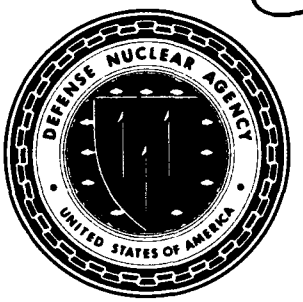

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Evaluation of Residual Radioactivity in Human Tissues Associated with Weapons Testing at the Nevada Test Site

McDonald E. Wrenn, et al.
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Department of Pharmacology
Salt Lake City, UT 84112

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Technical Report

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13. ABSTRACT *(Maximum 200 words)*

Residual radioactivity consisting of ^{238}, ^{239} & ^{240} Pu were measured by radiochemistry and alpha spectrometry in samples of bone and soft tissues from 100 autopsies of surgeries from northern and southwestern Utah and from control areas in Colorado and Pennsylvania. Based upon the isotopic ratio ^{240} Pu/^{239} Pu attributable to atmospheric weapons tests at the Nevada Test Site (NTS).

In addition, 110 thyroid tissue samples obtained from tissue blocks made at autopsy of veterans dying at the VA hospital in Salt Lake City in the 1940's and 1950's were measured for ^{129} I (half life 16 million year) and ^{127} I (stable) by neutron activation. The results were analyzed by year of death, by periods before and during atmospheric nuclear weapons testing at the NTS and by origin of usual residence. A model was developed to relate thyroid dose from ^{131} I to the measured $^{124/127}$ I ratios, and thyroid dose estimates were made based upon the measured ratios.

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EXECUTIVE SUMMARY

1. OBJECTIVE.

The main task of this project was to:

a. Determine the ^{129}I contained in approximately 100 human thyroid tissues through examination of autopsy samples; quantify the build-up over time of ^{129}I in human thyroids as related to nuclear testing; and assesses the thyroid dose to people who lived downwind from the Nevada Test Site and died in the early 1950's.

b. Determine the $^{239,240}Pu$, ^{234}U, ^{235}U and ^{238}U contained in current autopsy bone samples from persons resident in southern Utah during 1950-1960; calculate estimates of inhalation doses from the associated short-lived fission and activation products to lung, thyroid, bone and bone marrow. The determination of ^{234}U, ^{238}U and ^{235}U contained in lungs, liver, rib and vertebrae for approximately 40 sets of tissues from southern Utah, 40 sets from northern Utah, 15 sets from the Eastern U. S. (Pennsylvania) and 15 sets from the Western U. S. (Colorado), which were added later.

2. APPROACH.

a.1 Procurement of thyroid tissue blocks saved from the 1940's and 1950's at the Veteran's Administration Hospital in Salt Lake City, Utah.

a.2 Measurement of ^{127}I and ^{129}I in approximately 100 thyroid tissues by neutron activation analysis.

a.3 Develop a model for calculating thyroid dose from I-131 based upon residual I-129 and use this model to determine the thyroid dose for those thyroids analyzed.

a.4 Calculation of doses to thyroid from ^{131}I.

b.1 Procurement of current autopsy/surgery tissues such as lung, liver, vertebrae, ribs and femurs from residents of northern Utah, southern Utah, Pennsylvania and Colorado.

b.2 Determination of $^{239,240}Pu$ and ^{234}U, ^{235}U and ^{238}U in tissues by radiochemical separations and alpha-spectrometry.

b.3 Measurement of the isotopic ratio of $^{240}Pu/^{239}Pu$ in liver and bone to determine the contribution of plutonium burden from nuclear tests at the Nevada Test Site (NTS) relative to that from global fallout.

b.4 Calculation of radiation doses to bone marrow from inhalation of plutonium and fission/activation products.

3. CONCLUSIONS.

We measured $^{239,240}Pu$ in tissues obtained at autopsy or surgery from 42 subjects in northern Utah and 31 subjects in southern Utah. Samples of bone were obtained in all cases and, in most cases, we also obtained samples of liver, lung, kidney, spleen, thyroid and gonads. For control populations, 12 sets of tissue were obtained from Pennsylvania and 13 from Colorado.

We measured the $^{240}Pu/^{239}Pu$ ratio in a subset of these samples by mass spectrometry. Since the ratio for Pu from the NTS ranged from 0.02 to 0.06 with a mean of 0.03 and since the ratio for globally distributed Pu is about 0.18, the ratio measured in bone can be used to calculate the contribution of the NTS to the total $^{239,240}Pu$ measured. In northern Utah bone samples, we concluded that about 2% (range -6% to +5%) of the $^{239,240}Pu$ measured came from the NTS.

In 10 femur heads from southern Utah residents, the average concentration of $^{239,240}Pu$ did not differ significantly from bone from northern Utah. However, in three of the samples based on the measured ratio, a significant percentage of the $^{239,240}Pu$ activity came from the NTS. Two of these samples apparently came from people who had resided for long periods in Las Vegas, Nevada. One additional sample without a residential history has an elevated contribution from NTS Pu (50%), but not an elevated $^{239,240}Pu$ content. The seven remaining samples with 6% of the $^{239,240}Pu$ from the NTS had a concentration of 6 mBq/kg, 40% less than that found from northern Utah.

If we assume the average $^{240}Pu/^{239}Pu$ ratio in this sample of 10 was accumulated in southern Utah and not Nevada, we can calculate the dose to bone marrow for $^{239,240}Pu$ and any associated fission products. Using published fission product yields and an assumed $^{239,240}Pu/^{90}Sr$ ratio of 0.03 found in global fallout, we have calculated doses to bone marrow from inhaled alkaline earth beta emitting fission products as 37 mrads.

Nuclear weapons testing at the NTS in the 1950's resulted in extensive radioactive fallout deposition in the neighboring state of Utah. The isotopes of radioiodine were secreted in the milk of grazing cows, and subsequently irradiated the thyroids of those individuals consuming contaminated milk. Unfortunately, it was not generally realized that radioiodine was rapidly transported to man through milk until the late 1950's. Atom ratios ^{129}I (1.6×10^7y)$/^{127}I$ (stable) were measured in 110 sets of thyroid tissues, stored in

paraffin blocks since the 1940's and 1950's, taken at autopsy from individuals who may have consumed milk contaminated with ^{131}I from fallout of nuclear tests at NTS. A mathematical model based on exponential equations describing pathways involving radioiodine source terms, accumulation, transfer and losses of radioiodine in environmental, animal and human compartments is presented in this work. The model is designed to interpret the measured atom ratios $^{129}I/^{127}I$ in terms of the retrospective dose commitment of deceased individuals whose death occurred at a known time after a shot.

Neutron activation measurements have been made of ^{129}I and ^{127}I (stable) in sections of thyroids obtained from tissues embedded in paraffin after autopsy in the late 1940's and early 1950's. These tissues were selected from 618 normal thyroids from autopsy records of 1,058 persons. We now know there should have been readily detectable quantities of ^{131}I present in human thyroids from some areas in Utah in 1951, '53, '54 and '55 primarily through intake in milk. Because ^{129}I has a half life of 16 million years, little decay will have taken place in the samples stored only 40 years. The dose is proportional to amount of ^{131}I which was originally ingested, and the amount ^{129}I remaining can be related to the amount of ^{131}I which was originally ingested by an appropriate mathematical model incorporating yields at fission, deposition, transport, intake and uptake. The approximate atom ratio of $^{129/127}I$ found is 10^{-9}. The ratio of $^{129}I/^{127}I$ will be compared between thyroids obtained pretesting and during atmospheric testing. Year to year variation will be discussed, along with the implications for dose to the thyroid from ^{131}I. There was no statistically significant difference found between the mean value of $^{129/127}I$ ratios prior to and after the start of atmospheric testing at the NTS in 1951.

Although not statistically significantly different from zero, the difference (1.49-1.33 = 0.16) would be equivalent to a thyroid dose of 2 rads if we assume a mean delay of 150 days between a single contaminating event and death. There are also other sources of ^{129}I than nuclear weapons tests at the NTS, for example, global nuclear tests and the fuel reprocessing plants at Hanford, Washington.

PREFACE

The participation and assistance of many staff members are gratefully acknowledged, including but not limited to: Roberta Roswell, Laura Lewis, Philip Kinser, Herb Ruth, Jeanne Brennan, Rona Hoffman, Rose Moesser and Amy Halterman.

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The assistance of Scott Mossinger and Vicki Noble at Dixie Medical Center in obtaining pathology information was invaluable.

CONVERSION TABLE

Conversion factors for U.S. Customary to metric (SI) units of measurement

MULTIPLY → TO GET	BY	TO GET ← DIVIDE
angstrom	1.000 000 x E -10	meters (m)
atmosphere	1.013 25 x E +2	kilo pascal (kPa)
bar	1.000 000 x E +2	kilo pascal (kPa)
barn	1.000 000 x E -28	meter ^{2} (m^2)
British thermal unit (thermochemical)	1.054 350 x E +3	joule (J)
calorie (thermochemical)/cm ^{2}	4.184 000	joule (J)
cal (thermochemical)/cm ^{2}	4.184 000 x E -2	mega joule/m ^{2} (MJ/m^2)
curie	3.700 000 x E +1	*giga becquerel (GBq)
degree (angle)	1.745 329 x E -2	radian (rad)
degree Fahrenheit	$t\ k = (t°f + 459.67)/1.8$	degree kelvin (K)
electron volt	1.602 19 x E -19	joule (J)
erg	1.000 000 x E -7	joule (J)
erg/second	1.000 000 x E -7	watt (W)
foot -	3.048 000 x E -1	meter (m)
foot-pound-force	1.355 818	joule (J)
gallon (U.S. liquid)	3.785 412 x E -3	meter ^{3} (m^3)
inch	2.540 000 x E -2	meter (m)
jerk	1.000 000 x E +9	joule (J)
joule/kilogram (J/kg) (radiation dose absorbed)	1.000 000	Gray (Gy)
kilotons	4.183	terajoules
kip (1000 lbf)	4.448 222 x E +3	newton (N)
kip/inch ^{2} (ksi)	6.894 757 x E +3	kilo pascal (kPa)
ktap	1.000 000 x E +2	newton-second/m ^{2} ($N-s/m^2$)
micron	1.000 000 x E -6	meter (m)
mil	2.540 000 x E -5	meter (m)
mile (international)	1.609 344 x E +3	meter (m)
ounce	2.834 952 x E -2	kilogram (kg)
pound-force (lbs avoirdupois)	4.448 222	newton (N)
pound-force inch	1.129 848 x E -1	newton-meter (N*m)
pound-force/inch	1.751 268 x E +2	newton/meter (N/m)
pound-force/foot ^{2}	4.788 026 x E -2	kilo pascal (kPa)
pound-force/inch ^{2} (psi)	6.894 757	kilo pascal (kPa)
pound-mass (lbm avoirdupois)	4.535 924 x E -1	kilogram (kg)
pound-mass-foot ^{2} (moment of inertia)	4.214 011 x E -2	kilogram-meter ^{2} ($kg-m^2$)
pound-mass/foot ^{3}	1.601 846 x E +1	kilogram/meter ^{3} (kg/m^3)
rad (radiation dose absorbed)	1.000 000 x E -2	**Gray (Gy)
roentgen	2.579 760 x E -4	coulomb/kilogram (C/kg)
shake	1.000 000 x E -8	second (s)
slug	1.459 390 x E +1	kilogram (kg)
torr (mm Hg, 0° C)	1.333 22 x E -1	kilo pascal (kPa)

*The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.

** The Gray (Gy) is the SI unit of absorbed radiation.

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PLUTONIUM IN HUMAN TISSUES

1.1 INTRODUCTION.

During the 1950's, open air atomic weapons tests were performed at the Nevada Test Site (NTS). Radioactive debris from these tests drifted over parts of Nevada, Utah and Arizona usually depositing higher concentrations of fallout in parts of these states than in other parts of the country. Approximately one megaton of fission yield was detonated in the atmosphere over NTS (Ref. 43, 1).

Lyon *et al* (Ref. 30) reported excesses of childhood leukemia in residents of Utah living closest to the NTS in the decade following open-air testings at NTS compared to the pretesting period. Lyon divided the state into two parts, the southern part which he called "high fallout" and the northern part which he called "low fallout". Subsequent to this, Beck and Krey (Ref. 5) concluded from measurements of ^{137}Cs and $^{239,240}Pu$ residual in soil that the average per capita exposure in the southern areas of the state was not higher than in the northern part. In fact, in terms of the size of external exposure to individuals in Utah, the highest exposures were in Washington County in Southwest Utah in 1953 during a series of shots in the spring, the most important of which was shot Harry.

The purpose of this study is to measure long-lived residual radioactivity in tissues from older people who were young adults or older at the time of the nuclear tests in the 1950's. Our objective is to test whether there is residual plutonium in these tissues, whether it differs from control areas, and whether the isotopic composition can be used to apportion exposure between a local source (the Nevada Test Site) and global fallout. The only suitable isotopes for such measurements are ^{239}Pu and ^{240}Pu, which have long residence times in human bone and liver.

Based on any excess of $^{239,240}Pu$, an estimate could be made of dose to lung and bone marrow from known or assumed ratios of plutonium to fission products and appropriate inhalation and metabolic models.

Another aspect of this study was to measure the $^{240}Pu/^{239}Pu$ atom ratios in liver and bone of southern and northern Utah residents. These measurements are very helpful in estimating the fraction of plutonium in human body originating from NTS rather than

global fallout of nuclear weapons testings. On the average, plutonium from atmosphere tests from Nevada had an isotopic ratio varying between 0.02 and 0.06 with a mean of about 0.03 in 1953 (Ref. 21), whereas, the global fallout has an average isotopic ratio ($^{240}Pu/^{239}Pu$) of 0.18 (Ref. 6).

1.2 MATERIALS AND METHODS.

1.2.1 Sample Collection.

Human tissues obtained from more than 44 autopsies in northern Utah, were from people presumed to have lived in Utah during open air testing at the Nevada Test Site. Among the tissues collected at surgery from orthopedic operations in southern Utah were 15 femurs from hip replacement operations and 7 knees (patellae) which were measured for $^{239,240}Pu$, besides five ribs, six vertebrae and nine livers from autopsy. Originally, we had planned to collect 40 sets of autopsy tissues from southern Utah, but changes in the autopsy rate in this sparsely populated area of the state prevented the collection of this many samples at autopsy. Accordingly, bones obtained during surgery were substituted in order to increase the sample size. In addition, thirteen sets of tissue were collected both from Colorado and from Pennsylvania. The sample size by population and tissue type sample is shown in Table 1. In this report, we only report the results from samples of bone and liver, since these were the tissues highest in concentration and also had the longest residence time for plutonium. It is generally believed that the mean residence time for plutonium in human bone is on the order of 100 years and, in liver, may be anywhere from 10 to 40 years.

1.2.2 Radiochemical Determination of Plutonium.

Determination of Pu in soft tissues was carried out by a method reported by Singh *et al* (Si 78). The detailed description of the method is as follows:

1.2.2.1 Sample Preparation. Transfer 500-1000g of tissue to a 4-L beaker and add 1-2 dpm of ^{242}Pu tracer. Add just enough concentrated nitric acid to immerse the tissues and cover the beaker with a watch glass. Heat gently over a magnetic stirrer hot plate until frothing ceases. Raise the temperature slowly to approximately 100°C and continue

Table 1. Number of tissue samples analyzed (N) for Plutonium by geographic area.

Tissue	N. Utah	S. Utah	Pennsylvania	Colorado
Liver	42	9	12	13
Lung	34	7	12	11
Tracheobronchial lymphnodes	0†	0†	6	
Kidney	34	8	7	10
Spleen	NA	NA	6	10
Gonads	NA	NA	6	3
Thyroid	NA	NA	3	6
Ribs	39	5	11	6
Vertebrae	37	6	10	11
Femur	3	15	0	0
Sternum	0	0	11	5
Knee	0	7	0	0

† Lymphnodes were not separated from lung.

NA Not available.

heating until the volume is reduced to approximately 100 mL. Heat at higher temperature and add a few drops of concentrated HNO_3 occasionally until a clear solution is obtained. At this stage, add 200 mL of 1:1 HNO_3:H_2SO_4 mixture and heat vigorously until all the nitric acid is driven off.

Add a few drops of HNO_3 occasionally with constant heating until a clear colorless solution is obtained ensuring almost complete decomposition of organic material. Remove most of the sulfuric acid by evaporation before proceeding further. In cases of tissues containing refractory plutonium oxide, the tissues, particularly the lung, must be treated with hydrofluoric acid or by fusion to ensure the complete dissolution of refractory oxides. However, this is not required for tissues from the general population exposed to fallout plutonium which is readily soluble in nitric and hydrochloric acid.

1.2.2.2 Procedure. Add 300 mL of 1:3 HCl to the clear solution thus obtained and boil for several minutes. Cool and add 1 mL of iron carrier (100 mg Fe/mL) and swirl the beaker for proper mixing. Add ammonium hydroxide very gently until precipitation is complete (the pH of the solution should be 8 or greater). The precipitate is gently heated with constant stirring for fast settling and then allowed to stand overnight for complete precipitation. Remove the supernatent after centrifugation of the precipitate in a 250 mL centrifuge tube. Dissolve the precipitate in 4-5 mL of concentrated HNO_3 and reprecipitate $Fe(OH)_3$ with ammonium hydroxide. Plutonium is coprecipitated with iron hydroxide along with several other metals. Repeat the process several times to ensure the complete removal of sulfate ions. The precipitate thus obtained is free of sulfate ions and is dissolved in a minimum volume of 1:1 HNO_3; the acidity of this solution is determined by titrating a 100µL aliquot against a standard sodium hydroxide solution. The acidity is adjusted to 3 M by adding a calculated volume of nitric acid of appropriate concentration.

1.2.2.3 Solvent Extraction. Heat the solution thus obtained gently and add 25 mg $NaNO_2$ (solid $NaNO_2$ is preferred since it does not increase the volume). Cool the solution to room temperature and add an equal volume of 25% TLA (pre-equilibrated with 3M HNO_3 for 10 min). Shake gently for 10 min and centrifuge for 20 min at 2000 rpm. Vigorous shaking should be avoided to prevent emulsion formation. Remove the aqueous phase. Add the second organic phase to the first extract. Add an equal volume of 10 M HCl to the total organic phase and shake for 10 min. Centrifuge for 10 min and remove the aqueous phase. Repeat the process once again to ensure the complete removal of thorium. Finally, wash the TLA phase with an equal volume of 1:1 HNO_3 to remove iron and

uranium and scrub the plutonium with an equal volume of 2 M H_2SO_4 (contact time is 10 min). Remove the aqueous phase into a beaker and repeat the scrubbing with 2M H_2SO_4 once again. Remove this aqueous phase from the first scrubbing. Evaporate the solution to dryness and electrodeposit plutonium on a platinum planchet. Sometimes, while separating the aqueous phase, some organics from TLA become entrained with H_2SO_4 which might interfere in electroplating. To avoid this possibility, add several drops of HNO_3 when black floating organics are present. The HNO_3 should completely decompose the organics in the presence of H_2SO_4.

1.2.2.4 Electrodeposition. *Apparatus:* The plating cell consists of an elongated 22-mm cap which holds a 1-oz polyethylene bottle with the bottom removed. The cap, which has space for an 18-mm diameter platinum plating disk and a nickel backing disk, may be firmly screwed into the polyethylene bottle forming a leak-tight plating cell. A threaded brass bushing is molded into the cap, thus making the electrical contact with the platinum disk cathode by clip leads. The cell is supported on a brass pedestal which is heavy enough to remain stationary in an ice water bath. The anode is a 1.59-mm diameter platinum disk riveted at one end. It is connected through a constant speed stirrer to the positive outlet of the power supply. A power supply furnishes a constant current ranging between 0-10 A and a constant voltage ranging between 0-30 V.

Procedure: Add 1 mL of 2 M H_2SO_4 to the beaker in which the solution, obtained after scrubbing with 2 M H_2SO_4, evaporate to dryness and heat gently at low temperature on a hot plate before transferring to the plating cell. Wash two times with 1 mL of 2 MH_2SO_4 dropwise with 3-4 drops extra to obtain the desired pH of the plating solution. The volume should not exceed more than 3-4 mL. Electroplate at an initial current of 1.2 A for 1 h. Quench the electrolyte with 3-4 drops of ammonium hydroxide at the end of 1 h. Dismantle the cell and rinse the platinum disk with distilled water, followed by alcohol and flame it to red heat over a burner to convert plutonium to oxide. Determine the plutonium recovery and isotope composition after counting the disk with a surface barrier silicon diode (Ortec, Inc.) and multichannel analyzer, which permits energy discrimination against naturally-occurring alpha emitters, which might not have been completely eliminated by the radiochemical procedure.

1.2.2.5 Standardization. The counting efficiency of the counter and energy calibration was determined with an electrodeposited standard source containing ^{242}Pu, ^{239}Pu, and ^{238}Pu which have their major alpha energies at 4.90, 5.16, and 5.50 MeV, respectively.

Plutonium in bone specimens were determined by a method reported by Singh *et al.* (Ref. 38). The detailed description of the method is as follows:

Sample Preparation: Transfer a weighed amount of tissue into proper size beakers and add 1-2 dpm of ^{242}Pu tracer. Add just enough concentrated nitric acid to immerse the tissue and cover the beaker with a watch glass. Heat gently on a hot plate until frothing ceases; then raise the temperature slowly and continue heating without boiling the nitric acid. Continue heating with nitric acid vigorously until most of the organics are removed. Heat further with nitric acid with occasional addition of H_2O_2 until the evolution of brown fumes ceases, indicating almost quantitative removal of organic materials.

Procedure: Add 200 mL of 1:3 HCl to the solution obtained after wet ashing with HNO_3 and H_2O_2 and boil for several minutes and cool. Add ammonia gently and neutralize until precipitate formation starts (normally around pH 4). Heat this solution to boiling and add a sufficient volume of 10% oxalic acid with constant stirring to precipitate ~10% of calcium available in solution and heat slowly to
550 °C.

Dissolve calcium carbonate thus obtained in a 1:1 HNO_3 and adjust the acidity to 4 M by titrating 100 µL aliquot with a 0.1 N NaOH and adding the required amount of nitric acid of appropriate concentration. Proceed for solvent extraction as described earlier.

1.2.3 Isotopic Ratio Measurements.

Alpha spectrometric methods can not be used to determine the isotopic ratio of $^{240}Pu/^{239}Pu$ because of very close energies of ^{239}Pu and ^{240}Pu (5.16, 5.11 MeV for ^{239}Pu and 5.17 and 5.12 MeV for ^{240}Pu). However, mass-spectrometry is a very appropriate technique to determine the atom ratios of $^{240}Pu/^{239}Pu$. The plutonium discs containing plutonium (used for alpha-spectrometric measurements) were sent to Battelle Pacific Northwest Laboratories (BPNL), where Pu was leached from the disc, purified through ion exchange column and collected on ion-resins, and was subjected to mass-spectrometric analysis, which is a very standard procedure for measuring the isotopic ratio of Pu.

1.3 RESULTS AND DISCUSSION.

The concentrations of $^{239,240}Pu$ in various organs of former residents of northern and southern Utah, and two control populations, Colorado and Pennsylvania are given in Figures 1-4.

The results indicate that the mean concentration of $^{239,240}Pu$ was highest in liver among all populations except in the Pennsylvania population where the mean concentration of $^{239,240}Pu$ in sternum was slightly higher than all other tissues thereby suggesting that among soft tissues, liver accumulates the major portion of Pu in soft tissues, which is quite in agreement with ICRP publications (Ref. 24), and also in agreement with other measurements of Pu in control populations (Ref. 32).

Statistical analyses (t-tests) were performed to check the hypothesis that whether or not the mean concentrations of $^{239,240}Pu$ in liver of four populations are statistically significantly different. The results indicate that the mean concentration of $^{239,240}Pu$ in liver of the four populations are not significantly different from each other.

Statistical tests were also performed (Ref. 39) to check the hypothesis whether or not the mean concentration of $^{239,240}Pu$ in lungs of these four populations are statistically significantly different. The results indicate that the mean concentration of $^{239,240}Pu$ in the lungs of southern Utah residents which were higher than the mean concentration of $^{239,240}Pu$ in lungs of Pennsylvania population was significant. However, the mean concentration of $^{239,240}Pu$ in lungs of Colorado and Pennsylvania populations, northern

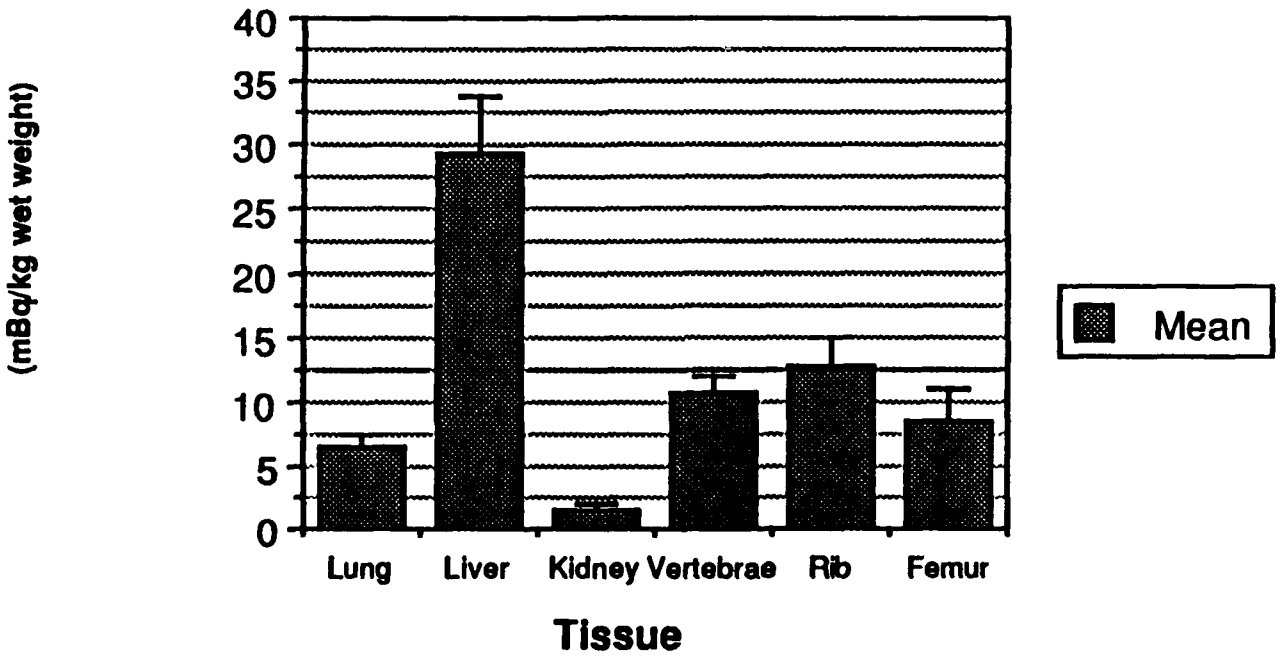


Figure 1. Concentration of Pu-239,240 in human tissue from N. Utah.

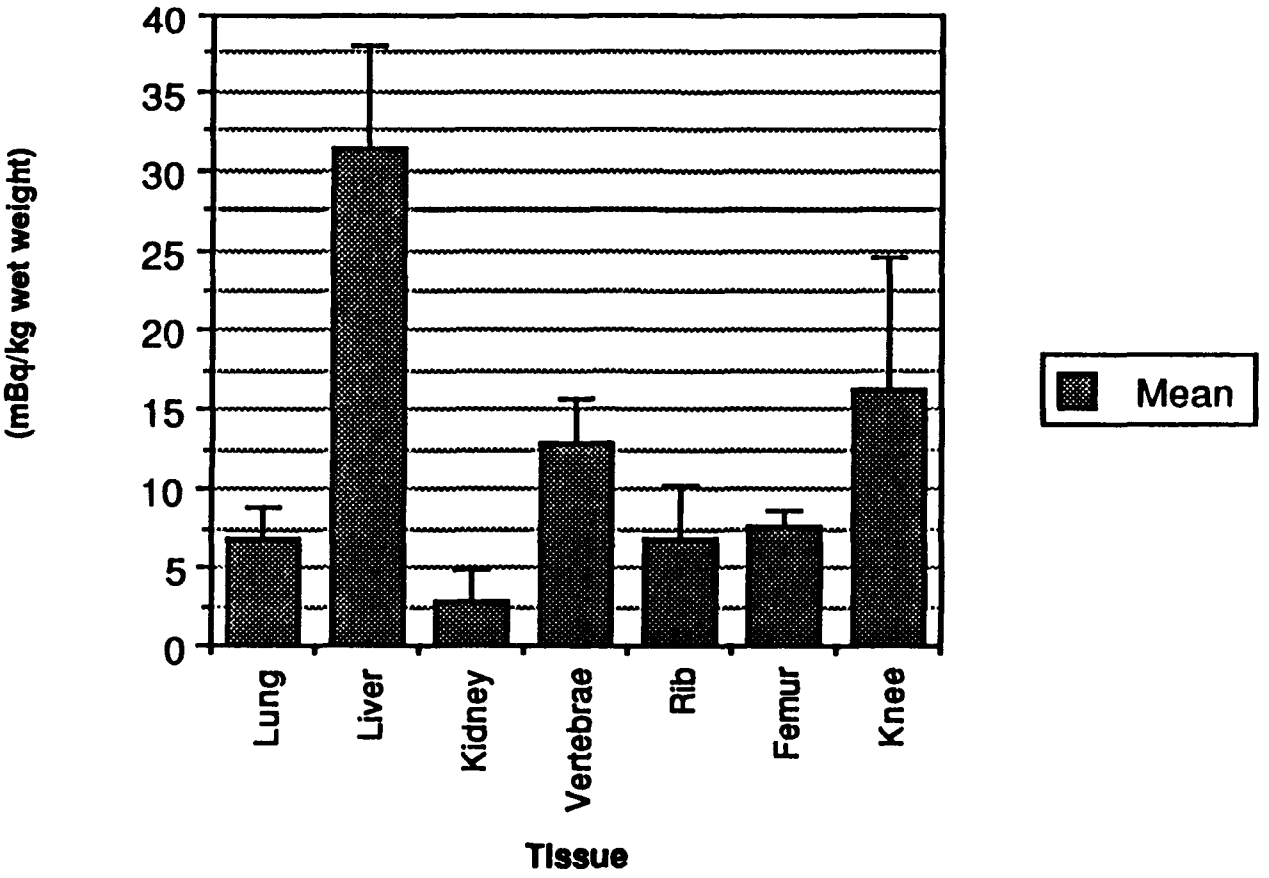


Figure 2. Concentration of Pu-239, 240 in human tissues from S. Utah.

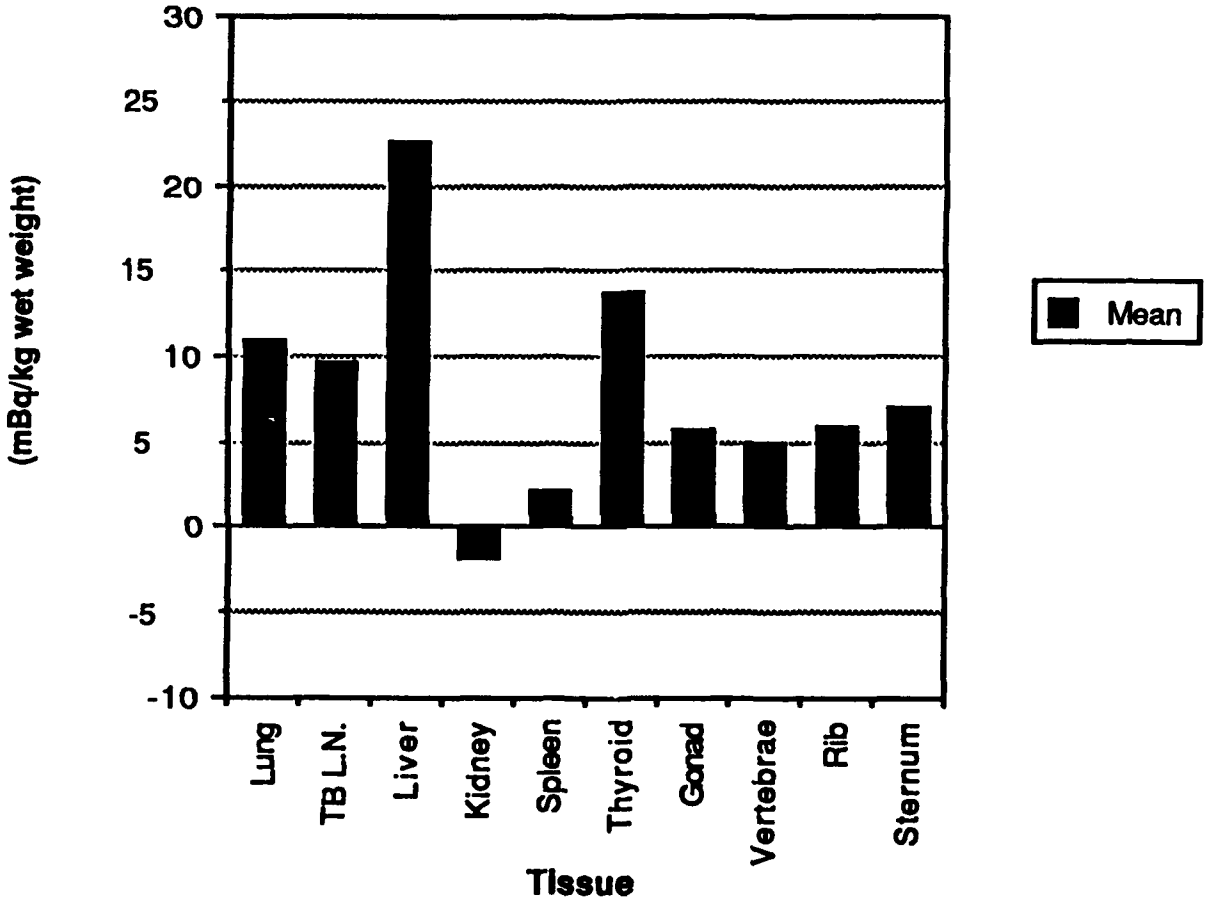


Figure 3. Concentration of Pu-239,240 in human tissues from Colorado.

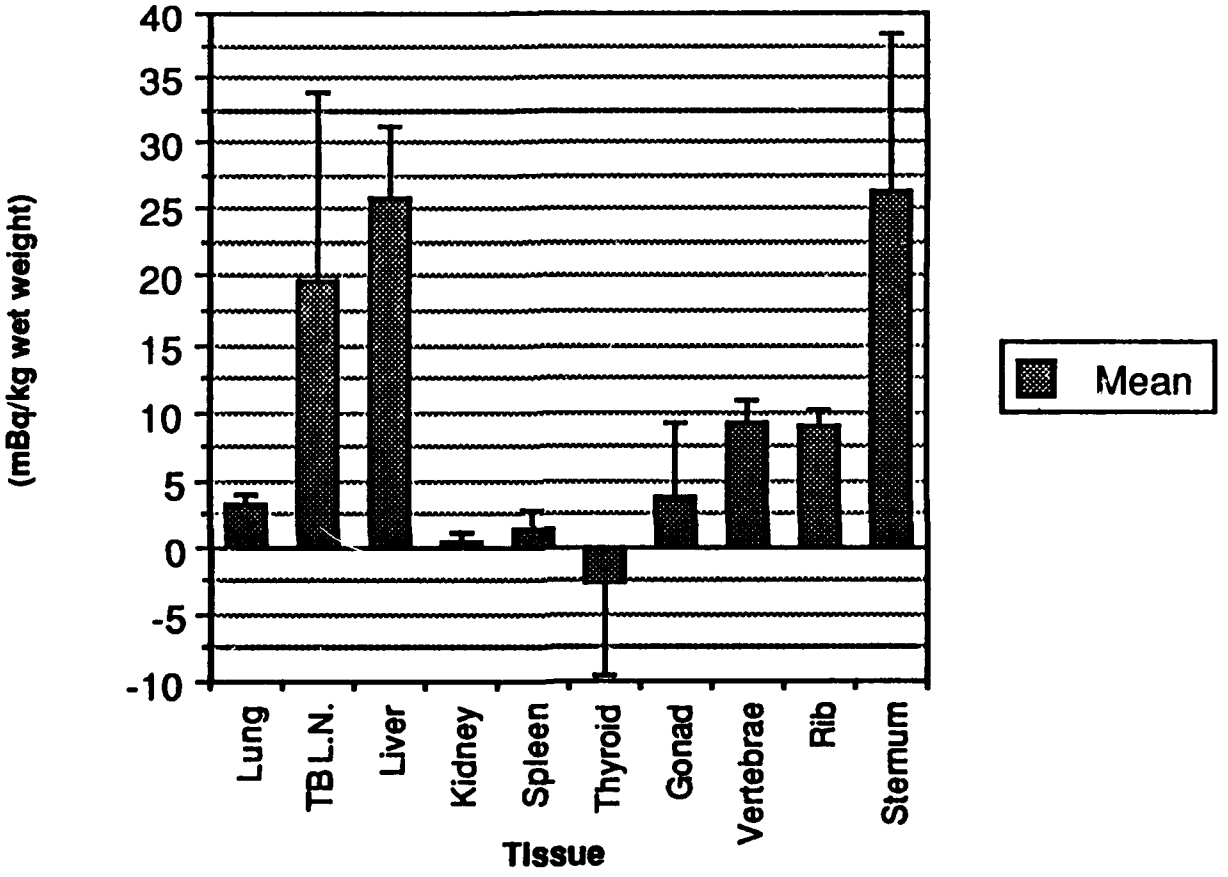


Figure 4. Concentration of Pu-239, 240 in human tissues from Pennsylvania.

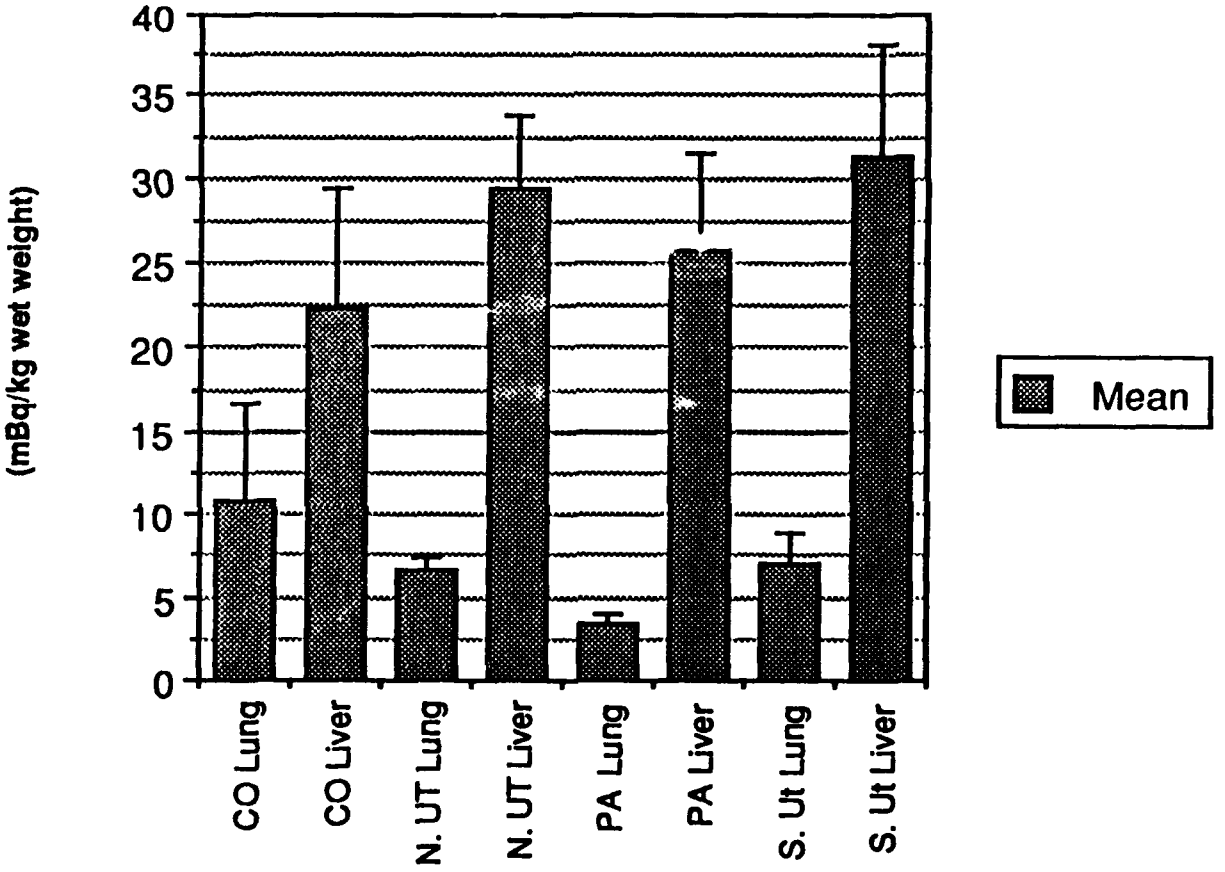


Figure 5. Concentration of Pu-239, 240 in the liver and lung from four populations.

and southern Utah populations, Colorado and northern Utah populations, Colorado and southern Utah populations and Pennsylvania and southern Utah populations were not significantly different from each other. A comparison between the concentrations of $^{239,240}Pu$ in lungs and liver of four populations are given in Figure 5.

1.3.1 $^{239,240}Pu$ Content In Bone.

The results of measurements of $^{239,240}Pu$ in samples of bone, including sternum, ribs, vertebrae, femur, and knee are shown in Figure 6 for samples collected from northern Utah, southern Utah (Washington County), Colorado and Pennsylvania. The mean values are plotted in mBq/kg wet weight and the number of samples of that bone type are shown above each mean. The error bars are one standard error of the mean. From the graph one can see that there appears to be no difference in the means within two standard errors between samples from northern and southern Utah.

For Pennsylvania, sternum is obviously higher than other samples and in southern Utah, knee appears to be higher than other samples.

In order to compare the values of plutonium among different types of bone samples, it is desirable to establish whether or not the distribution of values can be represented by a normal distribution and, if not, whether a log normal distribution could be used for statistical testing, or whether non parametric tests are necessary. Accordingly, we checked the samples included in Figure 6 for normality using the Kolmogorov-Smirnov one sample test, which gives a probability of obtaining a samples observed deviation from theoretical assuming the underlying population is normal. A low probability is evidence that the sample came from other than a normal distribution. No set was rejected for normality at $p = 0.11$. In order to add more assurance (perhaps we could have accepted a $p< 0.15$), we took the natural logarithm of the values and also conducted the normality tests on the logarithms of the measured concentrations. This resulted in some increase in the p's in the normality test; the log transforms were also not rejected as being normal.

Because the number of samples was limited in southern Utah, Colorado, and Pennsylvania, we wanted to know if we could combine the results from different bones,

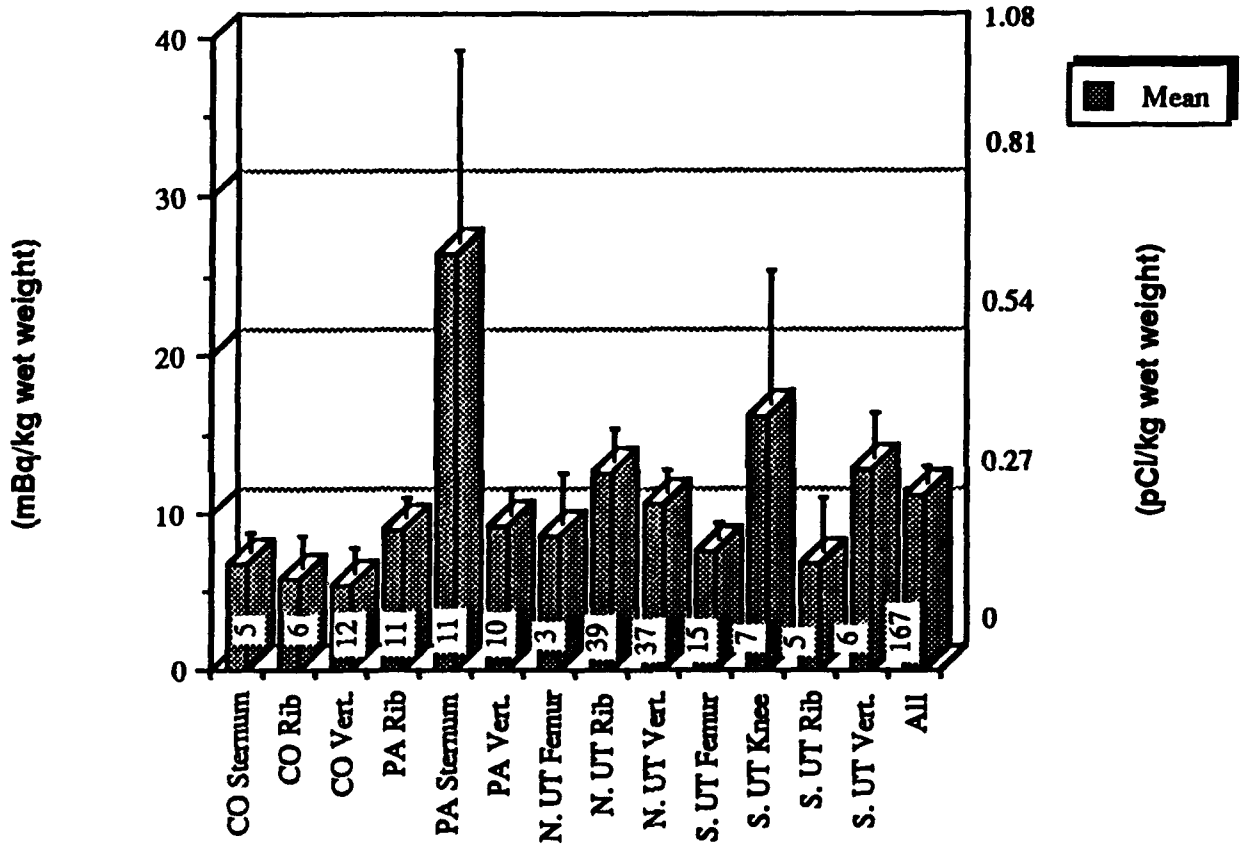


Figure 6. Pu-239, 240 in various bone from four geographic areas.

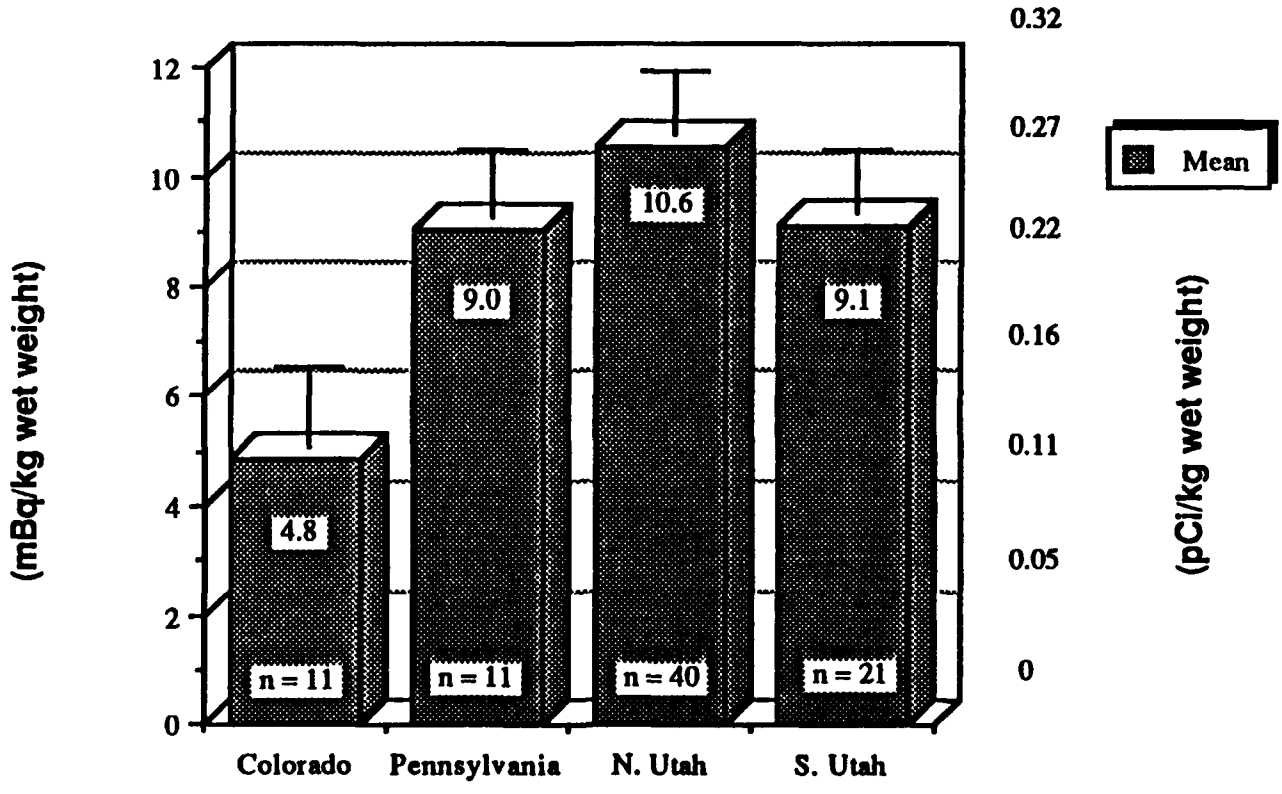


Figure 7. Concentration of Pu-239, 240 in vertebrae or ribs + femur.

when these samples came from separate autopsies and were not represented by a second bone sample from the same autopsy.

In Pennsylvania, eleven sternums and ten vertebrae were measured. We did a t test to see whether the difference in the means was significant. Using the log transformed variables, the difference between the means for sternum and vertebrae and sternum and ribs was significant in the Pennsylvania data ($p = 0.014$ and 0.011 respectively). However, using the untransformed data the difference was not significant, $p = 0.20$ and 0.17 for the comparison. Accordingly, we decided not to combine any of the data for sternum with that of ribs or vertebrae. The largest set of data on ribs and vertebrae came from northern Utah. In these samples a t test for the means on the untransformed variable gave $p = 0.38$ between vertebrae and ribs and on the log transformed variable $p = 0.37$. We concluded that the means for ribs and vertebrae were not significantly different even though the means differed by about 20%. Because rib and vertebrae samples were usually collected at the same autopsy, the two values are not independent and accordingly the two results were not combined as if they were independent. Thus, we combined the results for either ribs or vertebrae with other bones. An important question is whether or not the values for the femur differed from those of the ribs. There were only three femurs analyzed from northern Utah and the mean did not differ significantly from the mean in vertebrae or ribs ($p = 0.38$ and 0.50 for a normal distribution, and $p = 0.84$ and 0.56 for the log transformed variable).

In the tissues from southern Utah, we also collected knees which had a concentration of $^{239,240}Pu$ roughly double that in ribs and femurs. The knee was significantly higher than femur using the log transform ($p = 0.04$), but not for the untransformed data ($p = 0.13$). There were no statistically significant differences between ribs, vertebrae, and femurs for the southern Utah data.

We concluded it would be reasonable to group ribs or vertebrae plus femur, but that neither sternum nor knees should be grouped with ribs, vertebrae or femurs. Accordingly, the combined results in bone from Colorado (vertebrae), northern Utah (vertebrae plus femur), southern Utah (vertebrae and femur) and Pennsylvania (ribs) are shown in Figure 7. The highest mean was found in northern Utah samples (10.6 mBq/kg), but this was not significantly different from the means from southern Utah (9.1) and Pennsylvania (9.0). The mean for Colorado was 45% of that for northern Utah. This difference was statistically significant ($p = .02$ or 0.04) for the normal or lognormal distributions.

We do not know the reason for the lower mean for Colorado samples, but it may be due to geographic variation or to a difference in the part of the vertebrae collected by the pathologists.

1.4 ORGAN DISTRIBUTION.

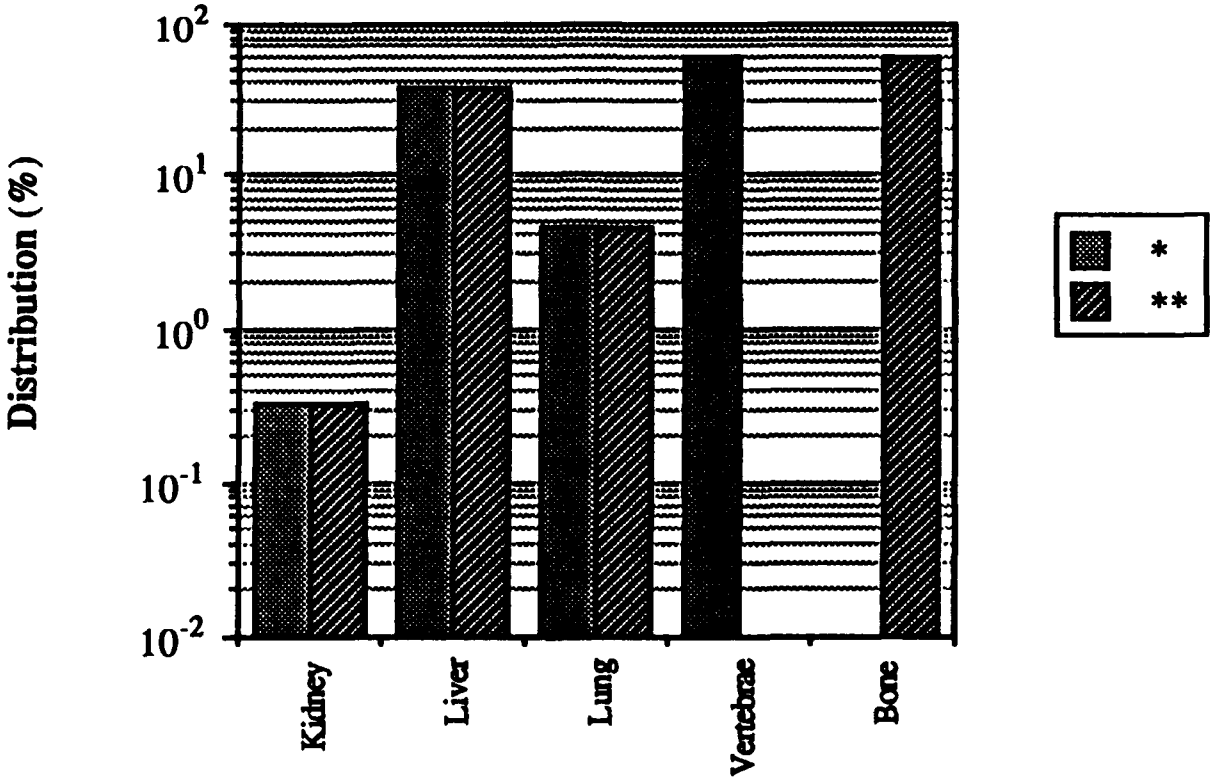
Organ burden of $^{239,240}Pu$ in each population was estimated by multiplying the mean concentration of $^{239,240}Pu$ in a particular organ with the reference man's weight of that particular organ. The results are given in Table 2. As can be seen, the skeletal burden of plutonium was highest of all organs in all populations, followed by liver and lung. The skeletal burden was estimated in two different ways: (I) based on the assumption that vertebrae represents the average skeletal concentration of $^{239,240}Pu$, since vertebrae has most commonly been used for estimating the skeletal burden of plutonium in world-wide studies and (II) the mean of all the bones available for a particular population as the average concentration of Pu in the entire skeleton. The skeletal burden of plutonium in all four populations, based on estimate from vertebrael concentration, did not show any particular trend as compared to the estimate from the mean concentration of Pu in all bones available for that population.

The percent organ distribution of plutonium for each population was calculated and the results are given in Figures 8-11. The results suggest that most of the plutonium is accumulated in liver and bone amounting to almost 86-98%. The remaining amount is mostly in lung. The skeleton contained a higher percentage of Pu as compared to liver in all four populations, however, the percentage skeletal burden varied from population to population. For example, plutonium was distributed almost equally in skeleton and liver in the Colorado population, liver containing 44% and skeleton containing 42.5% of the Pu. In all other populations, liver contained around 34-37% of Pu and the skeleton contained almost 59-62% of the Pu.

Table 2. Mean concentration (mBq/kg wet weight) and estimated organ burden of $^{239,240}Pu$ (mBq) in all populations +.

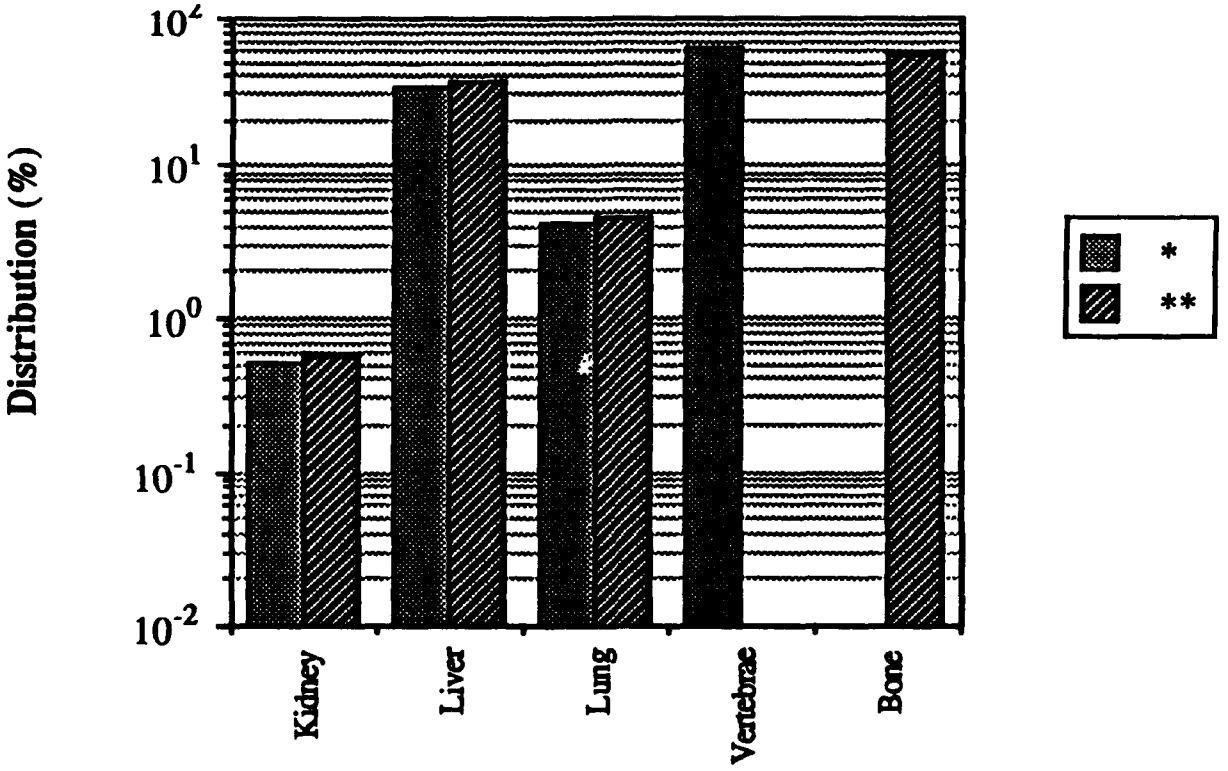
Population	Tissue	Mean	S.E. of Mean	Burden
CO	Gonad	5.55	10.147	0.194
CO	Kidney	1.44	0.387	0.446
CO	L.N.	9.497	17.153	0.142
CO	Liver	22.342	6.969	40.216
CO	Lung	10.791	5.969	10.791
CO	Rib	5.858	1.945	
CO	Spleen	2.032	0.605	0.366
CO	Sternum	6.808	1.247	
CO	Thyroid	13.522	9.896	0.270
CO	Vertebrae	4.844	1.462	38.752
CO	Bone	5.837	0.567	46.693
PA	Gonad	3.839	5.339	0.134
PA	Kidney	0.481	0.676	0.149
PA	L.N.	19.651	14.209	0.295
PA	Liver	25.715	5.679	46.287
PA	Lung	3.361	0.595	3.361
PA	Rib	9.015	1.269	
PA	Spleen	1.48	1.33	
PA	Sternum	26.331	12.136	
PA	Vertebrae	9.176	1.761	73.408
PA	Bone	14.841	5.745	118.725
NUt	Femur	8.418	2.547	
NUt	Kidney	1.525	0.37	0.473
NUt	Liver	29.318	4.412	52.772
NUt	Lung	6.565	0.92	6.565
NUt	Rib	12.865	2.039	
NUt	Vertebrae	10.74	1.22	85.920
NUt	Bone	10.674	1.284	85.395
SUt	Femur	7.573	0.975	
SUt	Kidney	2.819	2.016	0.874
SUt	Knee	16.37	8.084	
SUt	Liver	31.327	6.686	56.389
SUt	Lung	6.924	1.914	6.924
SUt	Rib	6.882	3.29	
SUt	Vertebrae	12.95	2.683	103.600
SUt	Bone	10.944	2.261	87.550

\+ At most only 2 figures are significant
* Assuming the vertebrae represent the skeleton
** Assuming the mean of all bone samples represent the skeleton



* Organ burden assuming the vertebrae represent the skeleton
** Organ burden assuming the mean of all bone samples represent the skeleton

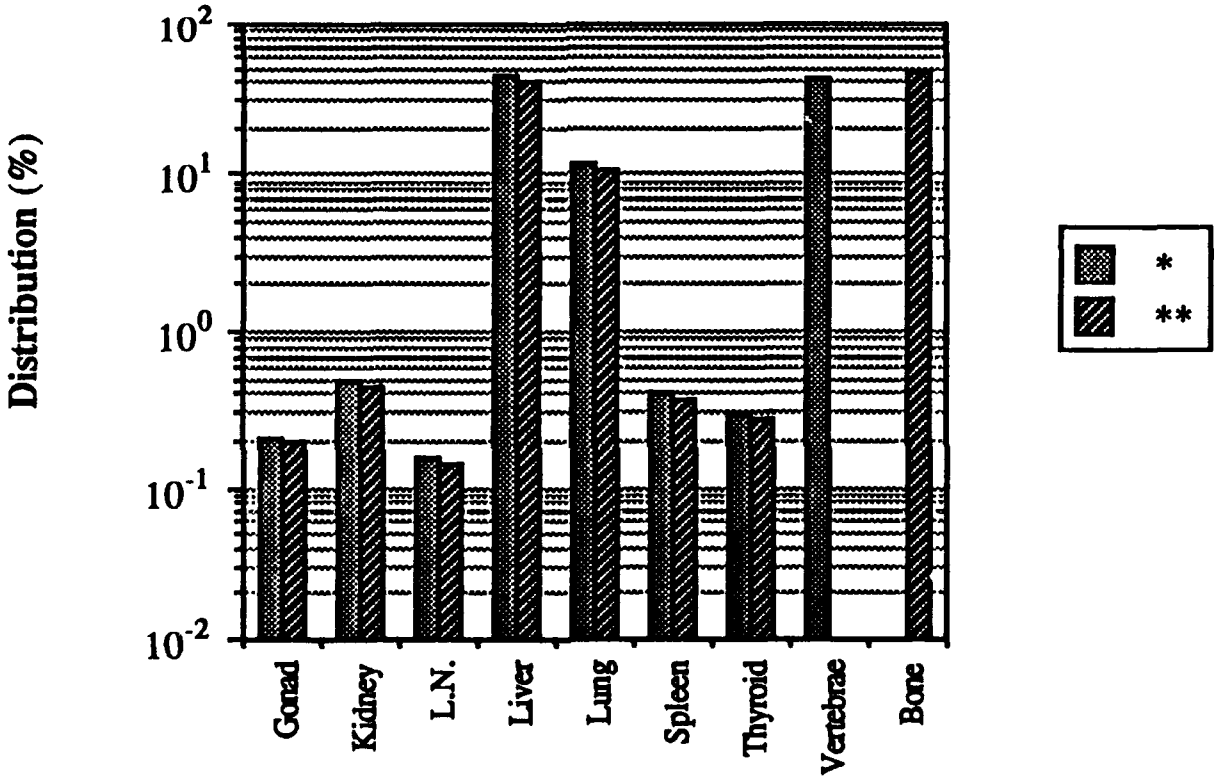
Figure 8. Percent organ distribution of Pu-239, 240 in human tissues from N. Utah.



* Organ burden assuming the vertebrae represent the skeleton

** Organ burden assuming the mean of all bone samples represent the skeleton

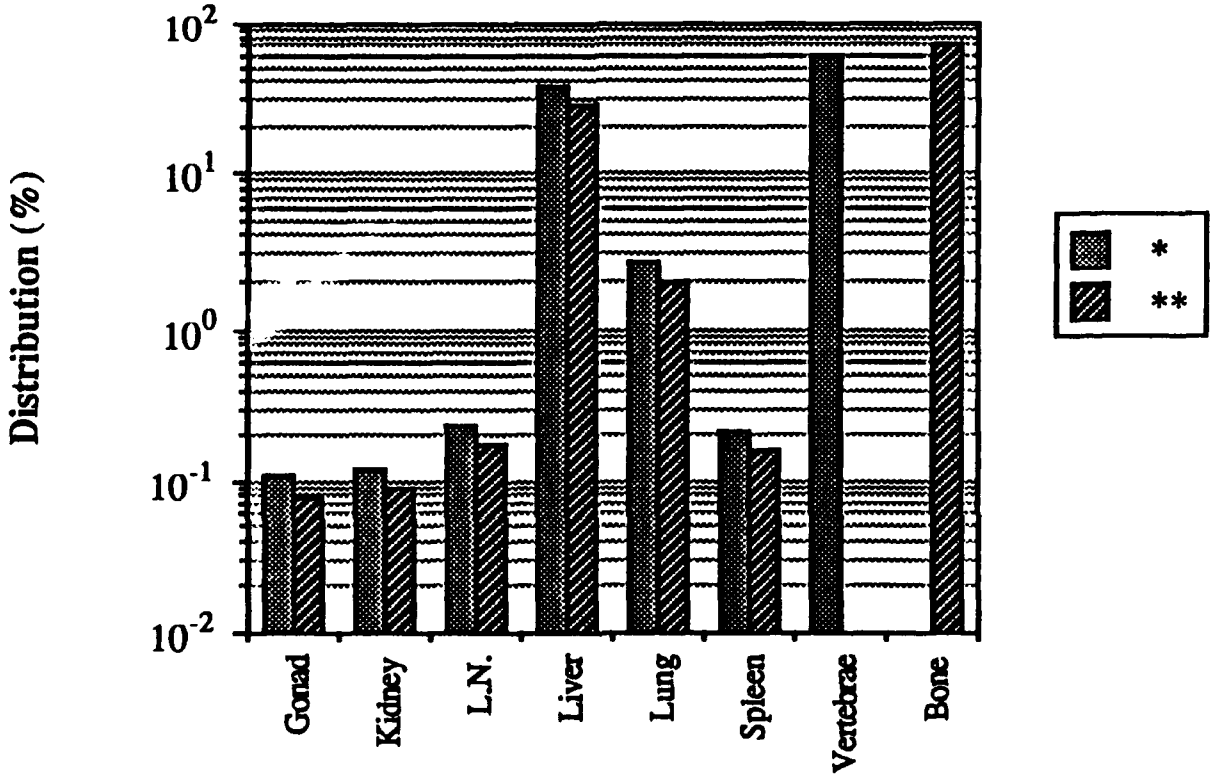
Figure 9. Percent distribution of Pu-239, 240 in human tissues from S. Utah.



* Organ burden assuming the vertebrae represent the skeleton

** Organ burden assuming the mean of all bone samples represent the skeleton

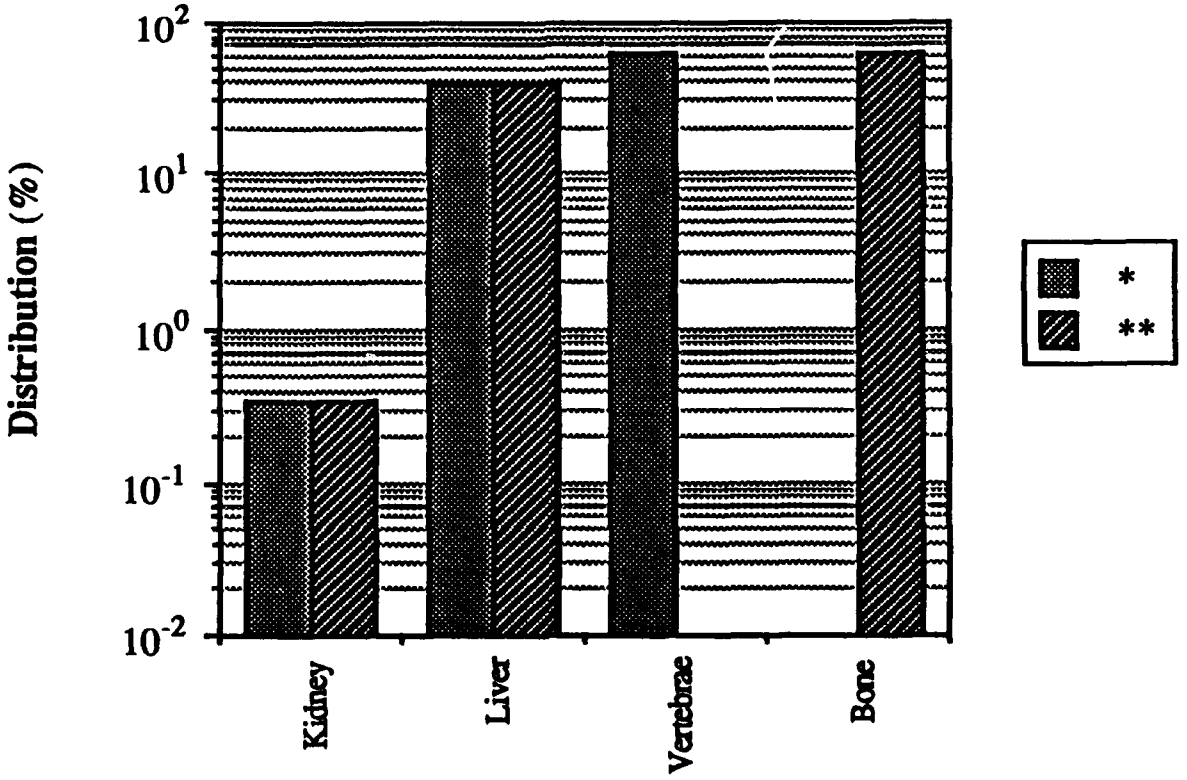
Figure 10. Percent organ distribution of Pu-239, 240 in human tissues from Colorado.



* Organ burden assuming the vertebrae represent the skeleton

** Organ burden assuming the mean of all bone samples represent the skeleton

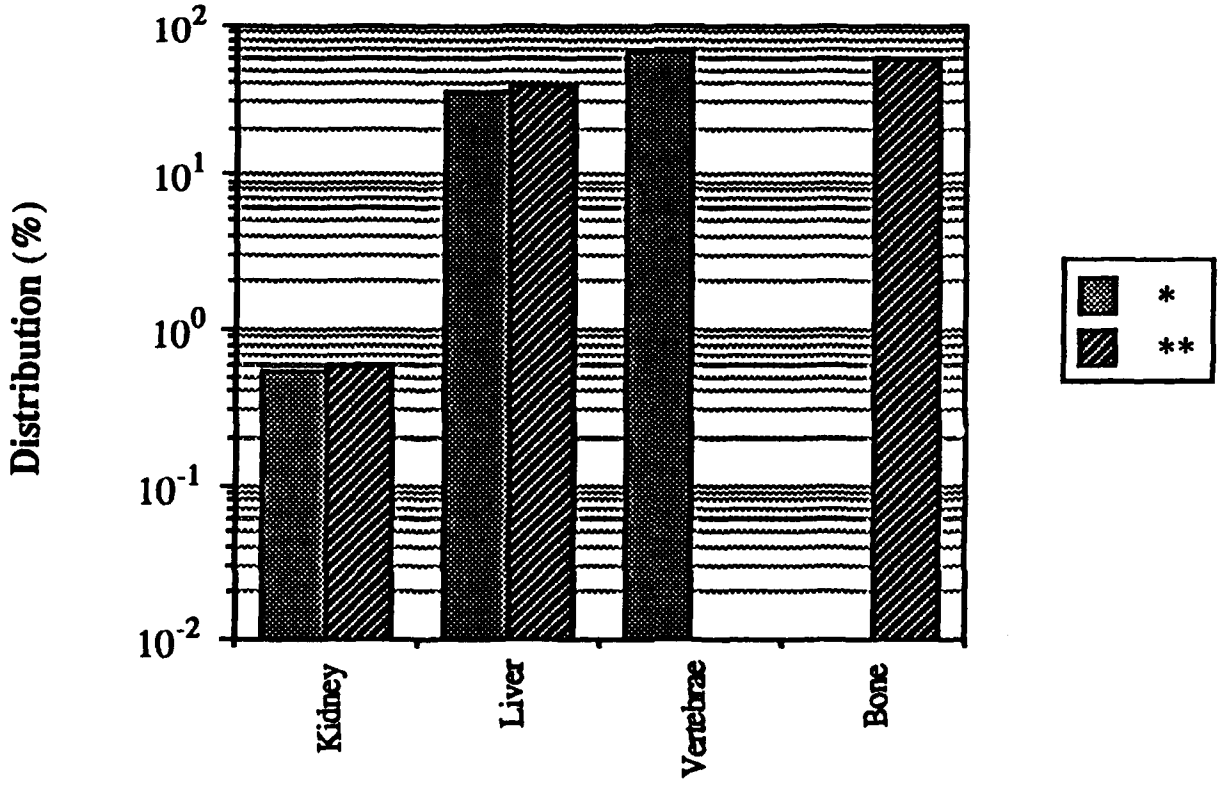
Figure 11. Percent organ distribution of Pu-239, 240 in human tissues from Pennsylvania.



* Systemic burden assuming the vertebrae represent the skeleton

** Systemic burden assuming the mean of all bone samples represent the skeleton

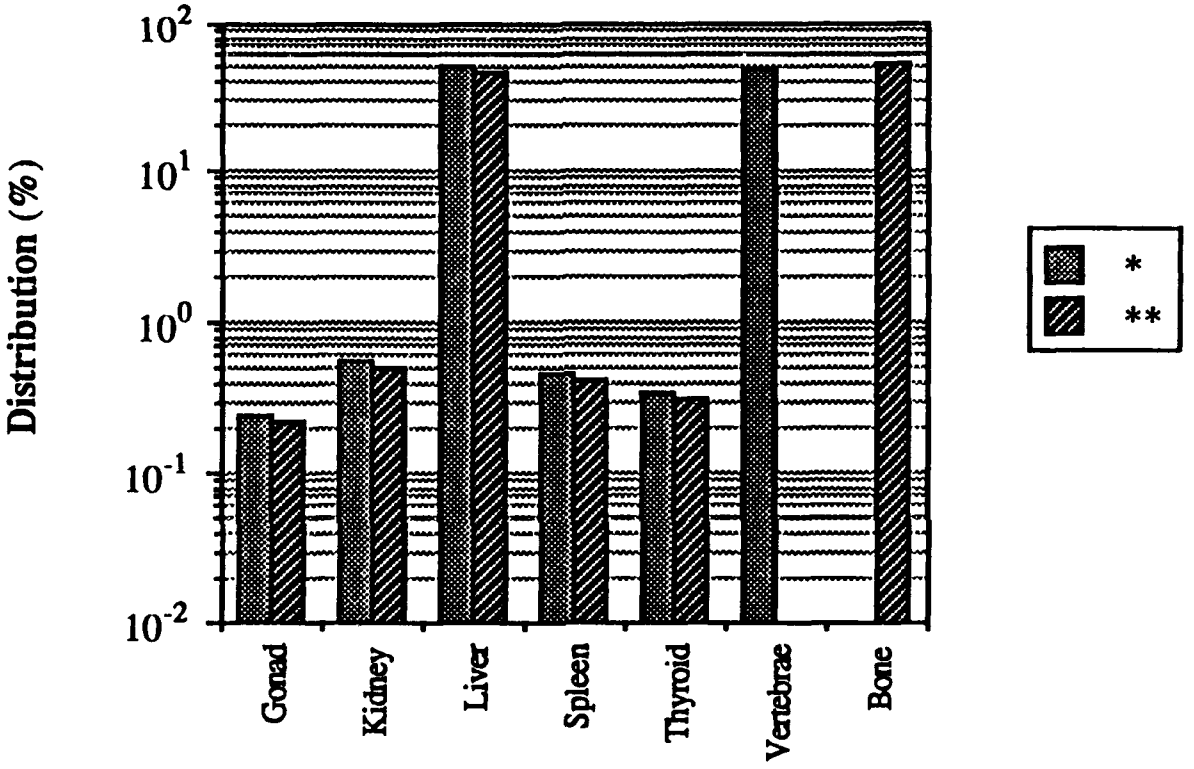
Figure 12. Percent systemic distribution of Pu-239, 240 in human tissues from N. Utah.



* Systemic burden assuming the vertebrae represent the skeleton

** Systemic burden assuming the mean of all bone samples represent the skeleton

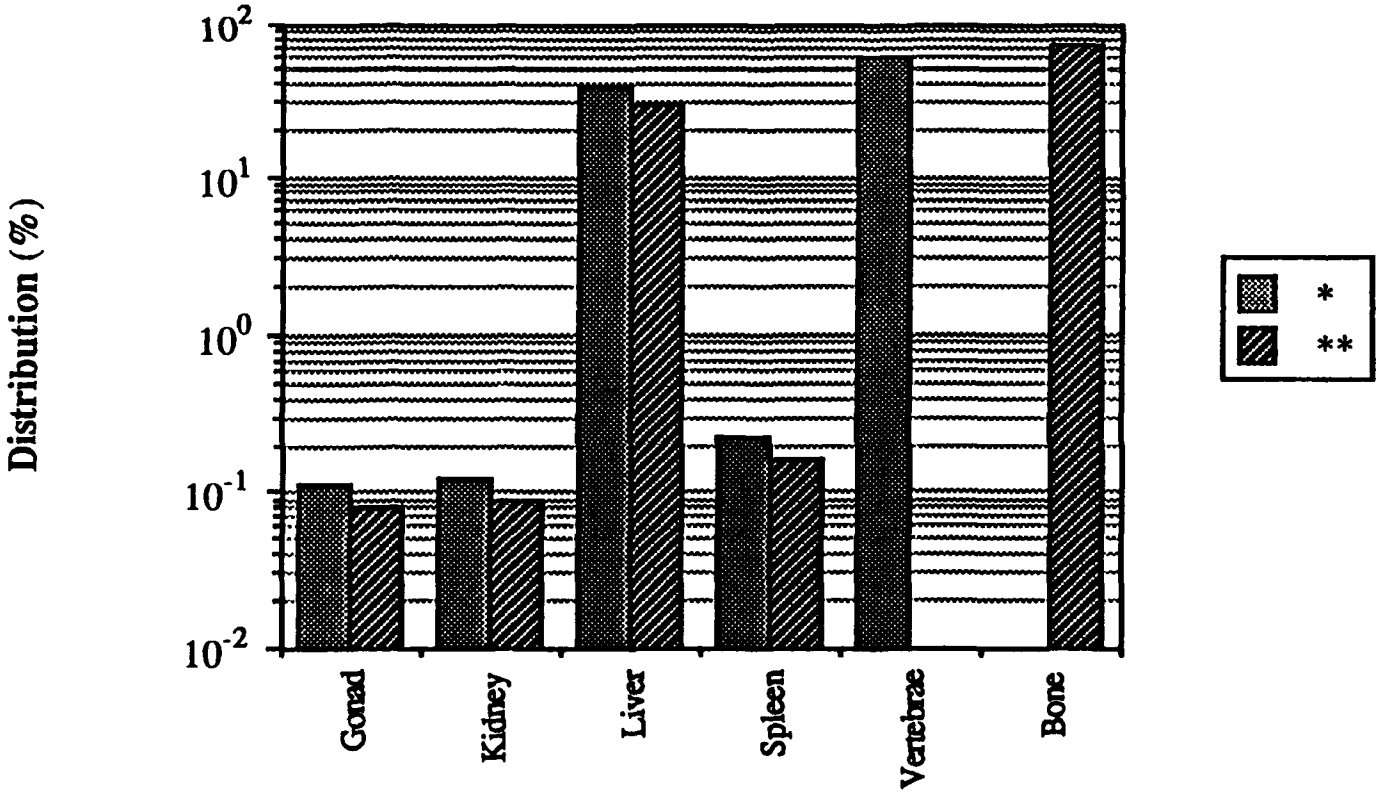
Figure 13. Percent systemic distribution of Pu-239, 240 in human tissues from S. Utah.



* Systemic burden assuming the vertebrae represent the skeleton

** Systemic burden assuming the mean of all bone samples represent the skeleton

Figure 14. Percent systemic distribution of Pu-239, 240 in human tissues from Colorado.



* Systemic burden assuming the vertebrae represent the skeleton

** Systemic burden assuming the mean of all bone samples represent the skeleton

Figure 15. Percent systemic distribution of Pu-239, 240 in human tissues from Pennsylvania.

Systemic organ burden of Pu was also estimated for all these four populations and the results are given in Figures 12-15. These results also suggest that in all populations skeletons contained around 60-70% of Pu and liver contained only 28-39%, except in Colorado where liver contained 46% of Pu as compared to the skeleton containing 53%.

All these results suggest that the initial distribution of Pu in liver and the skeleton may not be equal as suggested by ICRP (Ref. 24). The higher percentage of Pu in the skeleton as compared to liver may result from a shorter residence time in liver than in the skeleton and subsequent redistribution from liver to skeleton and, therefore, accumulates with time more in the skeleton than in liver.

1.5 ESTIMATE OF NTS CONTRIBUTION OF ^{239,240}Pu TO BONE.

The concentration of ^{239,240}Pu in Colorado bone samples was significantly lower than that from northern or southern Utah and Pennsylvania, and the concentration in Colorado liver was much less than that from other areas, although that difference is not statistically significant. We conclude that there is no significant difference in total ^{239,240}Pu among the northern and southern Utah and Pennsylvania sample sets. The fractional standard error in the mean for the northern Utah bones was approximately 11%. This means that the difference between means in northern Utah and any other area could be detected ($p = 0.05$) at approximately 1.9 standard deviations if the fractional error in the other sample set was about the same. We did not find any excess ^{239,240}Pu in southern Utah samples above that from northern Utah.

This does not mean that there was no contribution to the Pu burden in skeleton to the residents of southern Utah from nuclear testing in Nevada, only that such a contribution must have been less than that from global fallout and that possibly also the contribution from global fallout to the skeletons in southern Utah was less than that from northern Utah. This is in keeping with observations of Beck and Krey that global fallout values in Salt Lake City, Utah are anomalously high (Ref. 5, 6). Accordingly, any contribution from local testing in southern Utah must be considerably less than 10 mBq/kg of wet weight to bone.

Fortunately, there is a more sensitive way to test whether or not there was any contribution of atmospheric testing to the internal burdens in bone in southern Utah residents; that is to measure the isotopic ratio, ^{240}Pu/^{239}Pu. In nuclear tests conducted in

Nevada, the reported ratios are between 0.02 and 0.06, whereas, in global fallout, the mean ratio is about 0.18.

We measured this ratio in five paired vertebrae and liver samples from northern Utah, four pairs from southern Utah and ten femur heads from southern Utah. The shot specific ratios of $^{240}Pu/^{239}Pu$ in fallout reported by Hicks and Barr (Ref. 21) range between 0.02 and 0.06, generally increasing from 1951 through 1957. A general average of 0.032 has been assumed for the analysis here. The sensitivity of the analysis to the choice of this ratio is analyzed by assuming extreme values of this ratio in NTS fallout of 0.02 and 0.06. The mass spectrometric analyses were made by Battelle Pacific Northwest Laboratories on the Pu obtained from the platinum discs on which the Pu was deposited. The relative alpha activities were determined using the formula derived by Beck and Krey (Ref. 6) as follows:

$$\frac{Pu\ (NTS)}{Pu\ (Global)} = \frac{RG - RS}{RS - RNTS} \times \frac{(1 + 3.73\ RNTS)}{(1 + 3.73\ RG)}$$

RG = $^{240}Pu/^{239}Pu$ atom ratio in global fallout (0.18 ± 0.006)
RS = $^{240}Pu/^{239}Pu$ atom ratio in sample
RNTS = $^{240}Pu/^{239}Pu$ atom ratio in NTS fallout (0.032 ± 0.003)

The results are summarized in Table 3. For vertebrae from northern Utah, the results gave an average of –4% contribution from the Nevada Test Site, with a range among individual samples from –23% to +5%. We believe that results from one of the samples (ratio equal 0.237, –23%) was in error since analysis of plutonium from a sample of liver from the same autopsy did not show such a high ratio. If this sample is omitted, then we conclude that 1.6% of the plutonium in northern Utah samples came from the Nevada Test Site with a range between individual samples between –6% and +5% and 98.4% from global tests. Varying the assumed ratio for the isotopic contribution of plutonium of Nevada origin gives an average between 1.4 to 2.2% for the contribution from the Nevada Test Site to the Pu measured in vertebrae. Thus, the conclusion that there was very little plutonium from the Nevada Test Site present in tissues from northern Utah is inescapable based on this sample. The results in liver support the same conclusion. In the northern Utah liver, the estimate of the contribution from the Nevada Test Site averaged –1% with a range from –1.2 to 1.4%. In four livers from autopsy of long term residents of southern Utah, the ratio implied a 1.4% contribution from the Nevada Test Site among four samples and in vertebrae from the same autopsies a 2.7% contribution. In these vertebrae, the range associated with a variable ratio of the Nevada Test Site Pu leads to an estimate from 2.4 to 3.7%.

Table 3. Summary of Pu 240/239 Isotopic Ratios and Analysis of the Percentage of Pu Attributable to the NTS in Tissue Samples of Liver and Skeleton from Northern and Southern Utah

Area	Tissue No. Samples	240/239 (mean)	240/239 (range)	Best Estimate of Pu from NTS (%)	Range of Estimates of Pu from NTS (%)
Utah Liver	5	.1832	.172 to	–0.9%	–0.8 to –5.2%
Utah Vertebrae	5	.1887	.169 to	–2.9	–2.7 to –3.4
Utah Vertebrae*	4	.1766	.169 to	1.8	1.6 to 2.5
Utah Liver	4	.1771	.163 to	1.7	1.5 to 2.3
Utah Vertebrae	4	.1747	.163 to	2.7	2.4 to 3.7
Utah Femur	10	.1400	.071 to	23%	20 to 30.5
Utah Femur**	8	.1577	.092 to	9.3%	10.3 to 15.7

* Anomalously high ratio in 1 vertebrae omitted.
** Two low ratios omitted justified by lack of residence in Southern Utah during the 1950's.

Table 4. Isotopic ratio of plutonium in 10 femur heads from southern Utah residents in 1984–85.

Sample No.		Concentration of Pu-239+240	Atom Ratio ± Error	% Contribution from NTS to Pu
Utah	PNL	(pCi/kg)	240/239	Concentration
84SF6	7723	0.28 ± 0.09	0.1642 ± 0.0011	7
84SF7	77230	0.14 ± 0.05	0.1876 ± 0.0028	–3
84SF8	77227	0.03 ± 0.02	0.1510 ± 0.0034	14
84SF9	77229	0.14 ± 0.05	0.1611 ± 0.0028	9
85SF10	72236	0.35 ± 0.009	0.1561 ± 0.0016	11
85SF11*	77234	0.33 ± 0.12	0.0707 ± 0.0008	65
85SF12**	77235	0.32 ± 0.14	0.092 ± 0.0007	50
85SF13	77228	0.08 ± 0.40	0.1662 ± 0.0039	6
85SF15	77231	0.14 ± 0.04	0.1834 ± 0.0046	–2
85SF16†	77232	0.16 ± 0.08	0.0678 ± 0.0038	68

* This individual was living in St. George (1976 to date) and lived in Las Vegas before that.
** This individual was living in Beaver County, Utah.
† This individual is living in St. George (1976 to date) and lived in Las Vegas for 25 years before that.

Table 4 shows the isotopic ratios of $^{240}Pu/^{239}Pu$ in ten femur heads from southern Utah residents who underwent surgery in 1984 and 1985. The contribution of the Nevada Test Site Pu to total Pu from several of these was considerably higher than that found in vertebrae and liver. The two highest percentage contributions, 65 and 68%, came from individuals who apparently lived in Las Vegas, Nevada prior to 1967 and 1976, respectively. If we accept these ten as representative of southern Utah residents during the 1950's, then 23% of the plutonium measured in femur heads from persons undergoing hip replacement operations in southern Utah was due to Nevada Test Site sources. Since two of these had lived in Las Vegas during the period of open air testing, they should probably not be counted in this group. If the two high individuals who may have resided elsewhere during open air testing were eliminated, then the mean contribution is 9% (see Table 4).

Although some of the plutonium detected in bones from current southern Utah residents originated from the Nevada Test Site, this averaged one quarter to one tenth of the total plutonium content in the samples measured, and the bulk originated from global fallout.

1.6 CALCULATION OF DOSE COMMITMENT TO RED MARROW.

Using the average of 0.25 pCi/kg wet weight of $^{239+240}Pu$ found in 21 vertebrae, ribs and femurs (samples) from southern Utah, the net (ascribed to NTS) would be:

$$\text{pCi/kg} \times 0.226 = 0.056 \text{ pCi/kg}$$

where 0.226 is the fraction due to NTS, determined from the $^{240/239}Pu$ isotope ratios.

The weight of reference man skeleton is 10 kg, including marrow. Thus, the total skeletal content of plutonium from the Nevada Test Site fallout would not exceed 0.56 pCi.

Assuming the burden was accumulated in the skeleton primarily in 1953, that 29 years elapsed before death, and that bone turns over as a single compartment with first-order kinetics with a biological half-time of 100 years, then the amount originally deposited in skeleton would have been:

$$\text{pCi} \exp\left[+ \frac{(0.693) \times (29 \text{ years})}{(100 \text{ yr})}\right] = 0.68 \text{ pCi},$$

If we use the ICRP lung model for a class Y compound of Pu with a 1μ AMAD aerosol, which states that 5% of inhaled activity is transferred to blood and assuming as does ICRP that 45% of Pu reaching the blood is deposited in skeleton, then the amount inhaled would have been:

$$\frac{0.68}{(.45)(0.05)} = 30 \text{ pCi}$$

Earlier work suggested that the $^{239}Pu/^{90}Sr$ ratio in global fallout was 0.03 (Ref. 19), but in more recent work, Beck and Krey measured the $^{239,240}Pu/^{137}Cs$ ratio as 0.019 in soil. To convert this to a $^{90}Sr/^{239,240}Pu$ ratio, we use the relative deposition $^{137}Cs/^{90}Sr = 1.21$ at 4 hours post detonation from shot Harry as reported by Hicks (Ref. 20), to obtain a ratio $^{239}Pu/^{90}Sr = 1.558\%$ (see Table 5).

Then the ^{90}Sr inhaled can be inferred from the estimate of the $^{239,240}Pu$ inhaled (30 pCi) as 30 pCi/0.016 = 1.9×10^3 pCi.

The 50 year dose commitment to red bone marrow has been calculated for the short lived alkaline earths present in fallout for ^{89}Sr, ^{90}Sr (+ ^{90}Y), ^{91}Sr (+ ^{91}Y), ^{92}Sr (+^{92}Y) and ^{140}Ba (+^{140}La) using the dose equivalent commitments in ICRP-30 (Ref. 24, 14) and assuming a quality factor of 1. The activities relative to ^{90}Sr are taken from Hicks, assuming that the ratios in air are the same as the ratio deposited. The results are shown in Table 6.

The estimate of dose commitment from inhalation of the alkaline earths is 37 mrads and 0.4 mrads for $^{239,240}Pu$. Schlenker and Oltman (Ref. 36) have shown that plutonium is buried after skeletal remodeling in one human studied and it is clearly buried in animals (Ref. 3, 27). Although our plutonium dose estimate is an overestimate, using a quality factor of 20 would lead to a total dose-equivalent estimate of 8 mrem. The dose equivalent commitment is 45 mrem. These are small compared to the several rad or rem external dose delivered from this event. If, however, the true contribution of NTS fallout to total body $^{239,240}Pu$ was 9% and not 23%, the dose commitment estimates should be proportionately reduced to 18 mrads.

Table 5. Amounts of activity as ground deposition ($\mu Ci/m^2$) at 4 hours post detonation for Shot Harry 1953, for alkaline earth fission products.

Nuclides	$\mu Ci/m^2$ at h + 4
Sr-89	1.48 (-1)
Sr-90 (Y-90)	8.19 (-4)
Sr-91 (Y-91m, 90)	1.41 (1)
Sr-92 (Y-92)	1.42 (1)
Sr-93 (Y-93)	8.0 (-7)
Ba-139	3.14 (1)
Ba-140 (La 140)	6.86 (-1)
Ba-141 (La 141)	4.89 (-2)
Ba-142 (La 142)	1.56 (-4)

Table 6. Estimate of dose commitment to red bone marrow of southern Utah residents from inhaled alkaline earth fission products and $^{239,240}Pu$ from NTS Testing.

Class	Radionuclide	Estimate of Activity Inhaled (pCi)	Conversion Factor+ Sv/Bq	Dose to Red Bone Marrow (mrads)*	Committed Dose Equivalent (mrems)
D	^{90}Sr	1.9×10^{3}	3.36×10^{-7}	2.4	2.4
D	^{89}Sr	3.4×10^{5}	5.63×10^{-9}	7.1	7.1
D	^{91}Sr	3.3×10^{7}	1.23×10^{-10}	14.9	14.9
D	^{92}Sr	3.3×10^{7}	3.68×10^{-11}	4.5	4.5
D	^{140}Ba	1.6×10^{6}	1.3×10^{-9}	7.7	7.7
D	Σ Beta-emitting alkaline earths			36.6	36.6
Y	$^{239,240}Pu$	30	7.6×10^{-5}	0.4	8.4

*Includes the dose from the Y and La daughters. Note: 3.7×10^{2} Bq/pCi, 100 rems/Sv, quality factors of 1 for fission products and 20 for $^{239,240}Pu$ + Dose conversion factors are not available from ICRP for ^{139}Ba, the only other alkaline earth which might contribute significantly to the dose.

1.7 FINAL CONCLUSION.

Based on the measurement of $^{239,240}Pu$ activity in human bone and liver samples and measurements of the $^{240}Pu/^{239}Pu$ ratio by mass spectrometry, it is clear that the contribution of inhaled fallout to dose to bone marrow to residents of southern Utah in the 1950's could not have been very high relative to the external doses of radiation received. It was probably on the order of 0.01 rads or less, and even though this may not be very precise, it is known that external doses to bone marrow in residents of Washington county were on the order of 1000 to 4000 mrads, approximately one hundred times higher. This would appear to rule out inhalation as a significant route of exposure to bone marrow of residents of southwestern Utah during atmospheric nuclear testing at the Nevada Test Site in the 1950's.

SECTION 2

MEASUREMENTS OF $^{129}I/^{127}I$ IN HUMAN THYROID TISSUE FROM AUTOPSIES CONDUCTED IN THE 1940'S AND 1950'S

2.1 INTRODUCTION.

In 1957, the Windscale reactor accident in the United Kingdom released 20,000 Curies of ^{131}I into the environment and it was discovered that ^{131}I rapidly appeared in cows milk the next day. (Ref. 17, 7). This startling discovery led many to ponder the implications of past nuclear weapons testing, as ^{131}I was one of the fission products released in nuclear tests. At the Nevada Test Site (NTS), where about 1000 kilotons of fission were detonated in the atmosphere from 1951 through 1958, about 125 million Curies of ^{131}I was released. Because its rapid transport into milk had not been appreciated at the time, several individuals made retrospective estimates of the doses which may have been delivered to children in Utah, among them Mays and Tamplin (Ref. 34), and concluded that radioiodines from such tests may have exposed children in southwestern Utah to doses anywhere from 70 rads (Ref. 31) to 700 rads (Ref. 40). Some measurements were made in the field adjacent to the thyroid of healthy adults by gamma survey meters by Van Middlesworth (Ref. 42), with essentially negative results.

These substantial dose estimates prompted the PHS to initiate a study of thyroid disease and cancer in school children in southwestern Utah a decade later. That study found negative results in cancer induction relative to a control group in Arizona (Ref. 34). The study is being redone now with a subset of the original group studied and the preliminary report shows no statistically significant difference in thyroid neoplasms between the two groups (Ref. 35).

Recently, the Offsite Radiation Exposure Review Panel (ORERP) reevaluated radioiodine transport into children in southwestern Utah (Washington County) from these tests and concluded that the best estimate of dose was about 70 rads with a rather large confidence interval from 20 to 200 rads.

We wanted to develop a technique to make current measurements of doses to people from that area. It was pointed out by Lowell Woodbury that thyroid tissue blocks obtained by pathologists, if available, could be used to make current measurements. We knew that

^{129}I, with a half life of 16 million years (Ref. 29) could be measured by neutron activation analysis, and that ^{131}I was formed in definite proportions in fission relative to ^{129}I with fission chain yields of 0.99 and 1.00% respectively (Ref. 29). Based on measurements of ^{129}I, the dose from concurrently ingested ^{131}I could be calculated by use of a model (see Chapter 3, Modeling) relating the cumulative intake of both from milk. Such an estimate of dose can be made without knowledge of several important but ill known environmental parameters such as interception fraction of vegetation for fallout particles and amount of milk consumed, since these are inherent parameters associated with an individual's accumulation of ^{129}I.

2.2 MATERIALS AND METHODS.

We made a survey of 39 pathology laboratories in Utah and Nevada and found that the VA Hospital in Salt Lake City, Utah had saved tissue embedded in paraffin blocks from autopsies as far back as the 1940's. Over 1000 sets of these tissues were available from the 1940's and 1950's.

Autopsy reports and medical records of 908 persons who died at the VA Hospital from 1946 through 1955 were examined. Cases for analysis were selected on the basis of a normal thyroid condition, sometimes determined from examination of slides by a pathologist, and the absence of a history of therapeutic or diagnostic procedures using ^{131}I. Of these cases, 618 were selected as normal and the medical records of these were examined by an endocrinologist (Dr. Marvin Rallison) for diet, drugs, or other factors which might have altered normal thyroid metabolism of iodine. We located the tissue blocks for 150 cases out of the VA Hospital archives and analyzed 110, including 22 replicate analyses. We know that fresh milk was fed daily to the patients, but we do not know how much milk any individual patient consumed. The city and state of normal residence were also noted where available, although all cases died while in the VA Hospital in Salt Lake City. This permits us to analyze the results by location of normal residence.

The thyroid samples were retrieved in tissue blocks. Another slide was made and examined by a pathologist to confirm the tissue as normal thyroid, and most of the paraffin in which the tissue was embedded was cut away with a sharp knife. The rest of the parrafin was dissolved by shaking in xylene for 48 hours, and the tissues were then dried and stored in small plastic vials. Tests were conducted to investigate whether any significant amount of I was lost by this procedure. Tracer experiments suggested the

losses were small. Since the technique reported here depends on the measured ratio of $^{129}I/^{127}I$ in the samples, and not the absolute amount of ^{127}I (^{127}I is the only naturally occurring stable isotope of Iodine), any losses during preparation or analysis do not affect our conclusions other than reducing the precision of the measurements.

Samples were then prepared at Battelle Pacific Northwest Laboratories for neutron activation analysis by combustion in an oxygen atmosphere from which the volatalized iodines and some impurities were adsorbed onto cold charcoal. The charcoal was then heated, liberating the iodine and volatile impurities, which were then trapped by freezing in a quartz ampoule. The ampoule was subsequently irradiated in the N reactor for approximately 24 hours with a high thermal neutron flux. With each batch of samples, an ^{129}I free stable iodine source and a standard ^{129}I source were irradiated.

After removal from the reactor iodine was further chemically extracted by solvent extraction to remove activated impurities and known amounts of ^{125}I tracer were used to measure yield of recovery. The neutron capture reactions used for the iodine activation analysis are:

$$(1) \qquad ^{127}I\ (n, 2n)\ ^{126}I \xrightarrow[13\ day]{\beta^-, \gamma} {}^{126}Xe$$

$$(1) \qquad ^{129}I\ (n, \gamma)\ ^{130}I \xrightarrow[12.4\ hr]{\beta^-, \gamma} {}^{130}Xe$$

Neutron capture converts the ^{129}I to ^{130}I and a low background beta gated NaI crystal was used to count the ^{130}I. The ^{130}I identity is checked by both energy and decay rate (Ref. 11). On the same sample, ^{127}I was determined by measuring ^{126}I induced by an n, 2n reaction on the single stable isotope of ^{127}I using a high resolution GeLi detector. Thus, one set of measurements provided both stable iodine and ^{129}I measurements. The ratio of the two can be used to calculate the dose to the thyroid, assuming a normal ratio of stable iodine to thyroid mass. We used the ICRP value of 0.6mg iodine/gram of thyroid mass (ICRP 75) for dose calculations. The values reported in this section of the report are the measured ratios $^{129}/^{127}I$ in thyroid tissues.

The cumulative amount of ingested ^{131}I can be inferred from a measurement of the $^{129}/^{127}I$ ratio in the thyroid, modeling the intake regimen of both nuclides and accounting for the time between a single original deposition of fresh fission products on pasture and

the time of death. The results of the model are presented in this report (Section 3). For example, for a person consuming milk daily but dying 50 days after a contaminating event, the dose to an adult thyroid associated with 1 atom of ^{129}I per 10^9 atoms of ^{127}I would be 5.6 rads (see Figures 3-12). This conversion factor increases exponentially with time after 50 days with a doubling time of about 100 days, the mean half time of stable iodine in the adult human thyroid.

Because we analyzed more than 8 samples in each year from 1947 through 1955 (except 1949), we can analyze the change in ^{129}I with time before and during the major above ground tests. Unfortunately, no tissue blocks could be located for the years 1956 and 1957.

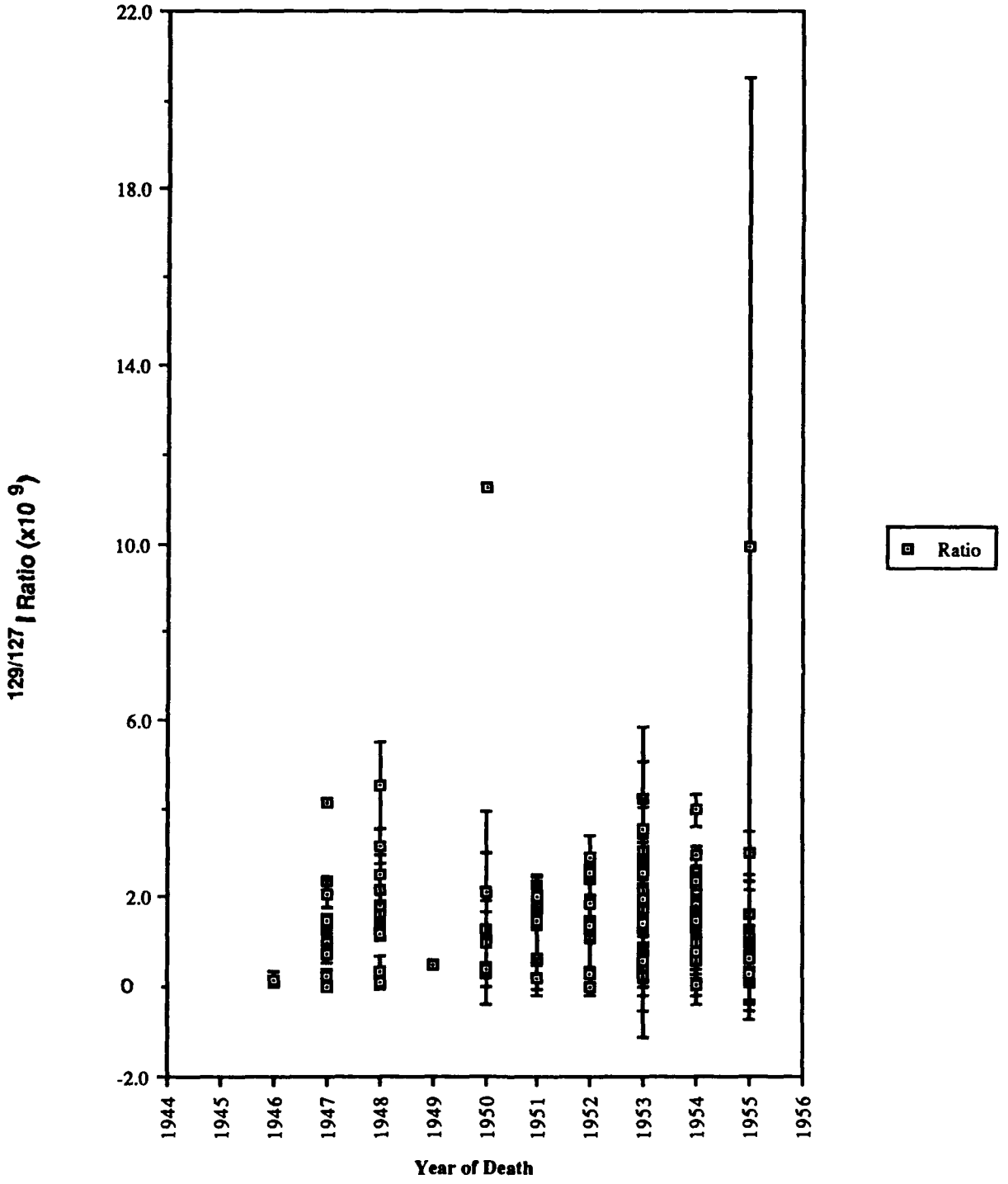
There are several sources of ^{129}I in the environment. The least important is naturally produced ^{129}I from spontaneous fission of ^{235}U and cosmic ray interactions with ^{238}U in the environment. The natural background atom ratio in seawater is estimated to be or less (Ref. 15). The background of thyroids from 1936 reflect only this and the analytical technique. Brauer reports less than 0.04 atom of ^{129}I per 10^9 ^{127}I atoms in thyroid samples prior to 1936 (Ref. 11). The other source is manmade nuclear fission. ^{129}I is released in global nuclear tests, in local tests at NTS, and from fuel reprocessing. The background we have measured in thyroids before 1951 (1946-1950) reflect all these sources except those for NTS tests, and can be used as a baseline against which to measure any increase observed after atmospheric testing began at the NTS in 1951.

2.3 RESULTS.

2.3.1 I-129/127 ratios in thyroid samples.

The results are given in Appendix B in terms of atoms of ^{129}I per billion atoms of ^{127}I. This relative designation (atoms of $^{129}I/10^9$ atoms ^{127}I) will be used from here on. 128 measurements were made on thyroid samples from autopsies from 1946 through 1955. These are analyzed as one set of 110 thyroids, of which 2 were omitted (108 data points. See footnote to Fig. 16). The mean $^{129}I/^{127}I$ ratio found was 1.44, the median 1.39 and the standard error of the mean 0.14. A test of normality (see Table 6) using the Smirnov Kolmogorov Test shows that normality would not be rejected (p=0.20). The distribution

Results for all 110 thyroids are shown. Note that there are two outliers, one in 1950 and one in 1955. The former occurred before atmosphere testing began at the NTS and the latter had an error overlapping zero.



The high value in 1950 could have resulted from a nuclear medicine test with I-131 which was in use then at the VA Hospital in Salt Lake City. This sample was from a person normally residing in California.

Figure 16. All $^{129/127}$I ratios by year of death.

Table 7. $^{129}I/^{127}I$ ratios in human thyroids + (outliers removed).

	all	before 1951	after 1951	Res. in Ut.	Res. Out Ut. Or Unknown
No. of Samples	108	34	74	69	39
Mean	1.437	1.330	1.486	1.470	1.379
Median	1.385	1.245	1.415	1.380	1.390
Kolmogorov Normality Test (p)	0.20	0.21	0.26	0.27	0.22

+ Units are in 10^{-9}. For example, the mean value for 108 thyroids is 1.437×10^{-9}.

of the measured $^{129}I/^{127}I$ ratios for all samples by year is shown in Figure 16 and the individual measured values are shown in Appendix B. The measured ratio is an order of magnitude higher than the ratio reported from a pre-nuclear age (pre 1936) thyroid (Ref. 11), of ≤ 0.04.

The data appears by eye to be non normal (no values less than zero are found and the means generally but not always exceed the medians). However, normality is not rejected $p=\leq 0.05$ for the subset of samples for those who died prior to 1951 ($p= 0.21$), those who died during or after 1951 ($p = .26$), those with normal residence in Utah ($p = .27$), and with unknown residence or normal residence outside of Utah ($p = .21$). All the autopsies were made on people who died in Utah at the VA Hospital.

Tests of significance have been made using either an assumed normal or log normal distribution. We have also used non-parametric statistical tests which give essentially the same results.

There was no significant difference in the means of the $^{129}/^{127}I$ ratios for those dying prior to atmospheric testing at the NTS (prior to 1951, mean 1.33 for 34 samples) and those dying in the period 1951-55 (mean 1.49 for 74 samples) ($p = 0.47$). This suggests that there was no significant contribution of atmospheric nuclear tests at the NTS to the thyroid burdens of ^{129}I in people dying in Utah up to 1955. Using the dosimetric model in Chapter 3 and if we conservatively assume a mean delay of 250 days between a test and autopsy, then 1 atom ratio implies 22.4 rads dose to the adult thyroid. Thus, the average dose to the group dying between 1951-1955 estimated by this procedure is $0.156 \times 22.4 = 3.5$ rads, which is not statistically significantly different from zero.

Another way to evaluate the data is to examine it year by year. Perhaps there were temporal trends both before and during atmospheric tests that by chance made combining the years 1946 - 1950 and 1951 - 1954 appear the same. The means by year and standard errors of the means are shown in Figure 17. Normality tests on the year to year data show that normality is not rejected at $p=0.05$ for any year (see Table 7). However, tests for differences in the means between any two years shows no significant difference between any two years using the t-test and the Mann Whitney U, the non-parametric analog of the t-test. However, using a t-test on the logs of the values, significant differences were found between the means for the years, 1947-52, ($p=0.024$), 47-54 ($p=0.047$), 52-55 ($p=0.015$) and 54-55 ($p=0.049$). The Wilcoxin rank sum test also showed significant differences for

these years excepting 52-55 (p=0.084) and in addition, showed for 48-55 the difference was also significant (p=0.038).

Finally, the means of individual samples are plotted grouped year by year (Figure 17). Although there are no statistically significant differences between pretesting and posttesting, it is possible that individual samples represent a significant departure from the mean and might reflect ingestion of iodine contaminated milk from nuclear tests. It is possible to pick the highest individual values and estimate the dose that that person might have received from ^{131}I if the difference above the mean were due to radioiodine from nuclear tests. The highest single value found in 1953 was 4.2 ± 1.6 for a person who died on October 4. If we use the pre-1951 mean ratio of 1.3 as background, the net ratio was 2.9 ± 1.6. If we take the time since the test previous to that, approximately 150 days, then one atom of ^{129}I per atom of ^{127}I implies 11.2 rads dose to the adult thyroid from ^{131}I. Using this single high value, the net dose estimated is 32 ± 18 rads. This estimate is not statistically significantly different from zero and, in addition, all sources of variation are not included in the standard deviation.

We measured 16 replicates and one triplicate, defined as samples for which there were either two or more parrafin blocks, or a sufficiently large mass of thyroid tissue in a single block to be divided in half. These replicates were generally consistent with each other. In some cases, the error associated with the measurement was very large; whenever the error exceeded 100%, we omitted the value as too uncertain. We either took the analysis with lower error or averaged them and propogated the error. There were 5 sets of multiple measurements (4 doubles and one triple) for which the counting error (± 10) was less than 50% for all samples (see Table 8). There were greater variations between "replicates" than that due to counting error alone, indicating an additional source of variance.

Although the results were near the detection limit for some samples in many samples the mass of the thyroid sample analyzed was sufficiently high, generally above 0.10 of a gram, that the amount found was well above the detection level.

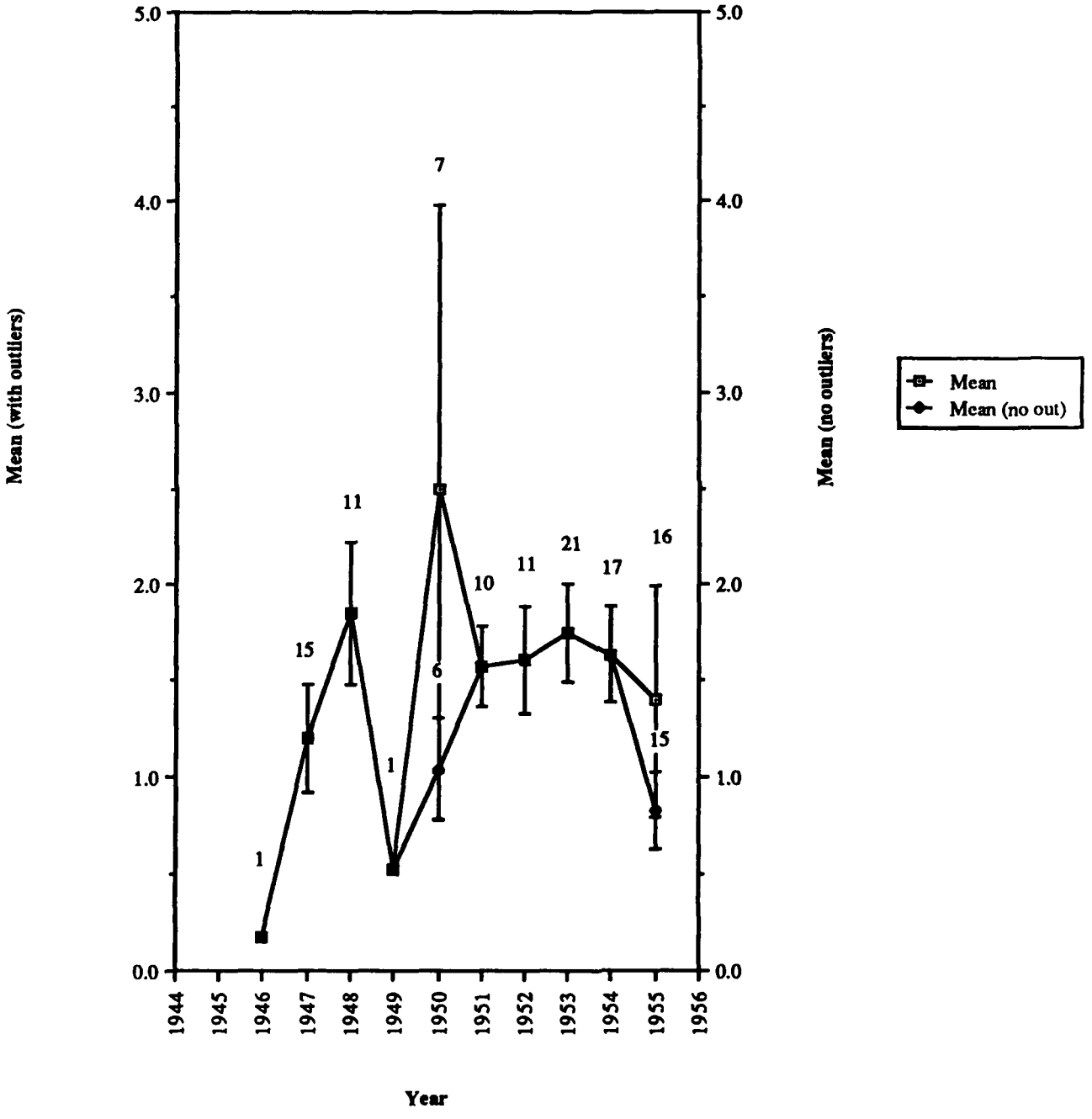


Figure 17. Mean $^{129/127}$I ratios by year of death

Table 8. Smirnov-Kolmogorov Tests for normality of the I ratios and their logarithms.

	Without Outliers			
	Normal		Lognormal	
	P	#points	P	#points
Ratio (all)	0.195	108	0.038	107
Ratio > 1	0.117	67	0.203	67
Died Before 1951	0.206	34	0.120	34
Died 1951 and after	0.264	74	0.055	73
Residence in Utah	0.272	69	0.086	68
Residence Out of Utah	0.215	39	0.113	39
Died 1946	.NA	1	.NA	1
Died 1947	0.234	15	0.200	15
Died 1948	0.310	11	0.181	11
Died 1949	.NA	1	.NA	1
Died 1950	0.335	6	0.286	6
Died 1951	0.270	10	0.154	10
Died 1952	0.330	11	0.230	10
Died 1953	0.276	21	0.186	21
Died 1954	0.354	17	0.183	17
Died 1955	0.211	15	0.251	15

Table 9. Results of replicate analyses of thyroid samples.

107A, B	0.29 ± 0.07
	2.09 ± 0.32
587	1.19 ± 0.08
	2.62 ± 0.29
	1.88 ± 0.14
683	2.08 ± 0.21
	3.00 ± 0.34
697	2.36 ± 1.09
	1.97 ± 0.20
455	2.17 ± 0.22
	2.18 ± 0.87

2.4 CONCLUSIONS.

1. It has been possible to measure ^{129}I by neutron activation analysis in old tissue blocks in paraffin of thyroid from the 1940's and 50's. The technique requires a very high neutron flux and very specialized counting equipment. A detection limit on the order of 0.1 to 1 atom of ^{129}I per 10^9 atom of ^{127}I was obtained.

2. A dosimetric model relating the ^{129}I to ^{127}I ratio in the thyroid is time dependent and at 150 days after the beginning of the ingestion of milk from a single contaminating event on pasture during which the cow continually grazes would be 11.2 rads per 10^{-9} atom ratio. There was no significant difference between the mean $^{129/127}I$ ratio measured in thyroids of people before and after the start of atmospheric nuclear testing at the NTS.

3. Applying the dosimetric model to the difference of the means of the measured 129/127 ratios before and during testing allows us to estimate the dose to the adult thyroids; for people dying in the VA Hospital who had milk as part of their diets, and presumably drank it, the estimate of mean dose was 1.7 rads, a number not statistically different ($p = 0.47$) from 0.

4. The highest single dose to an individual thyroid as estimated was 32 ± 18 rads, again not statistically significantly different from zero.

5. All things considered, there is no clearly definable positive signal (^{129}I) attributable to nuclear tests in these 128 measurements from 108 thyroids taken before and during atmospheric nuclear testing.

6. The levels of ^{129}I in thyroid pretesting in the late 1940's exceeded by at least an order of magnitude and possibly more the levels of ^{129}I which were measured with this technique in human thyroids in the prenuclear era.

Although we concluded that there were not any significant doses on the average to the adult, this does not imply that children could not have received doses on the order of several rads and possibly more in northern Utah in the early 1950's, since their metabolism is significantly different from adults for radioiodine, particularly in their ratio of intake in milk to thyroid mass.

SECTION 3

RETROSPECTIVE DOSIMETRIC MODELING FOR ^{129}I AND ^{131}I

3.1 INTRODUCTION.

Human thyroid tissues taken from autopsies conducted in the 1940s and 1950s and stored in paraffin blocks since that time recently became available for analysis of their ^{129}I (1.6×10^7y) and ^{127}I (stable) contents by means of neutron activation performed at the Battelle Pacific Northwest Laboratory to establish the $^{129}I/^{127}I$ atom ratios.

Over one thousand thyroid tissue blocks were potentially available at the Veterans Administration Hospital in Salt Lake City, Utah, from autopsies performed between 1946 and 1959. Medical records indicated that about half of these thyroids came from "normal" subjects, while the remaining were considered "abnormal." Pathologists at the University of Utah further examined the "normal" thyroid tissue blocks and their corresponding medical records for diet, drugs, and other factors which might have influenced normal iodine uptake. As consequence of this further examination, the number of "normal" subjects was reduced to less than two hundred.

The overall aim of the project was to evaluate retrospectively the doses received by preserved thyroids from exposure to ^{131}I (8.0 d) from nuclear tests performed at the Nevada Test Site (NTS) in the 1950s. To do so, a mathematical model was developed to interpret the recently measured atom ratio $^{129}I/^{127}I$ in thyroid tissue blocks of "normal" individuals in terms of the ^{131}I doses delivered retrospectively to these thyroids a short time after the shots through accumulation and transport involving the pasture, cow/milk thyroid pathway.

Neutron capture converts ^{129}I into ^{130}I through a (n,γ) reaction with a cross section of 9 ± 1 b (Ref. 29) and a (n,2n) reaction converts stable iodine ^{127}I to ^{126}I. A beta-gated NaI crystal is used to detect the beta and gamma radiations emitted by the ^{130}I, and a GeLi detector is used for measuring the ^{126}I gamma emissions. Neutron flux and irradiation time are controlled to minimize the triple

neutron capture by stable iodine. Further details on this analytical procedure and on the sample preparation and radiochemical procedures involved to remove interfering impurities, prior to gamma counting, such as radioisotopes of cesium and bromine, can be found elsewhere (Ref. 12).

3.2 BASIC ELEMENTS FOR MODELING.

The determinant element for modeling is the objective to be achieved with the model. In the present case, the objective of the model is to establish a realistic, but simplified, description of the environmental behavior of radioiodines to estimate retrospectively, based on the $^{129}I/^{127}I$ atom ratio measured in the thyroid blocks, the dose received by these organs due to ^{131}I uptake after nuclear tests.

Once the objective is established, one can then insert in the boxes of the general model representation, shown in Figure 18, the other basic elements to develop a specific model. In addition, one can disregard in Figure 18 the boxes representing those routes leading to doses to humans, which are obviously less important in a specific case. Accordingly, the less important routes for the radioiodines, the direct external radiation and the direct internal contamination, will be disregarded from hereafter. This simplifying procedure leads to a more straightforward representation of model boxes, as shown on the left of Figure 19. Thus, the basic model structure shown in Figure 19 is as follows:

(i) source terms - the nuclear tests in question with corresponding 129 and 131 fission decay yields;

(ii) relevant radionuclides - the radioiodines ^{129}I and ^{131}I;

(iii) relevant media - pasture, and in some instances one can include soil, because of resuspension in the case of ^{129}I;

(iv) animal/food - cow/milk for both radioiodines;

(v) target organ in humans - thyroid for radioiodines; and

(vi) dose to organ - dose estimate, including the evaluation of a dose factor, to the human thyroid.

The four intermediary boxes that appear in the model structure represented in Figure 19 constitute essentially a compartment model describing the pathway of accumulation, transfer, and losses of the radioiodines from the relevant environmental media to the target organ in humans.

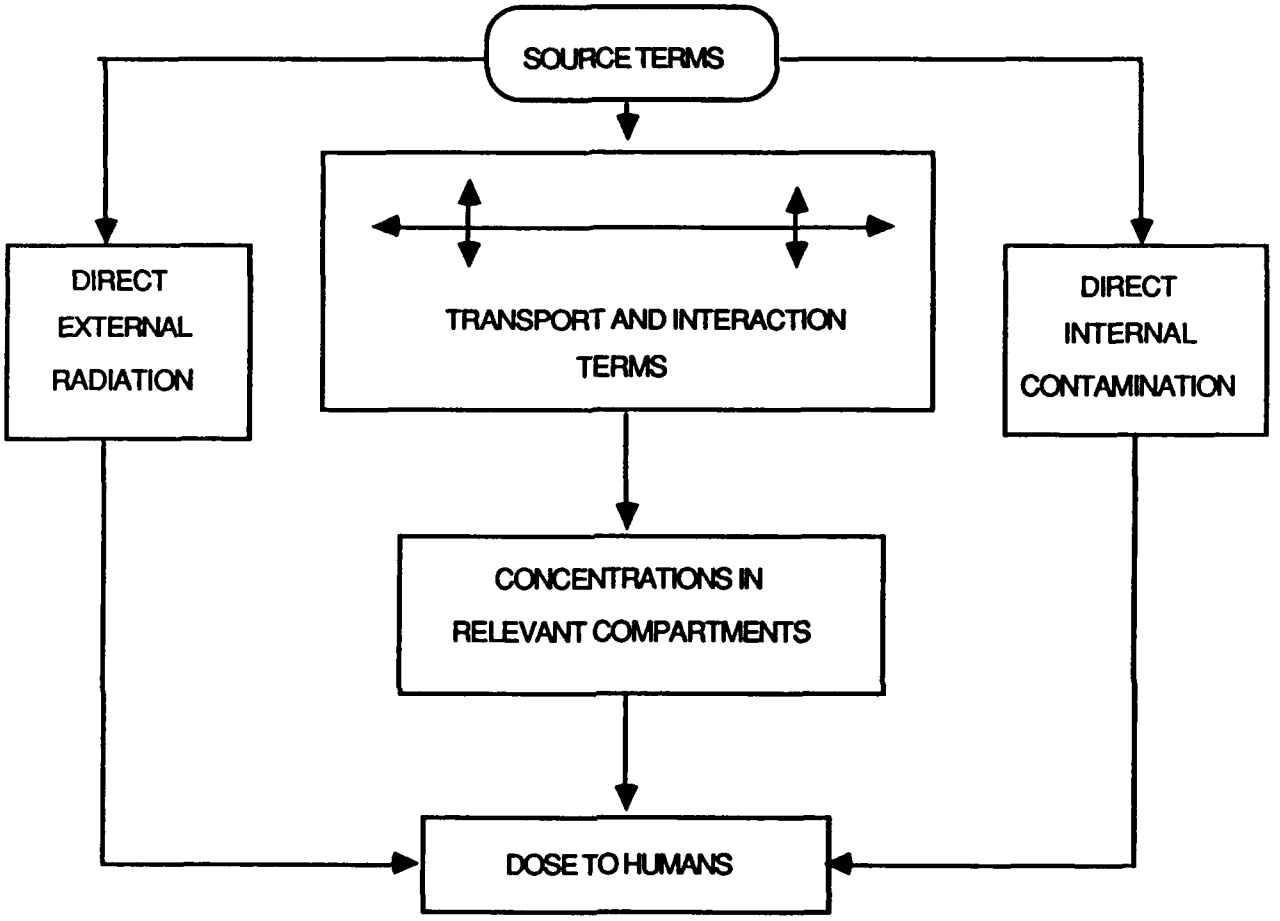


Figure 18. General compartment model representation: from source terms to dose to humans.

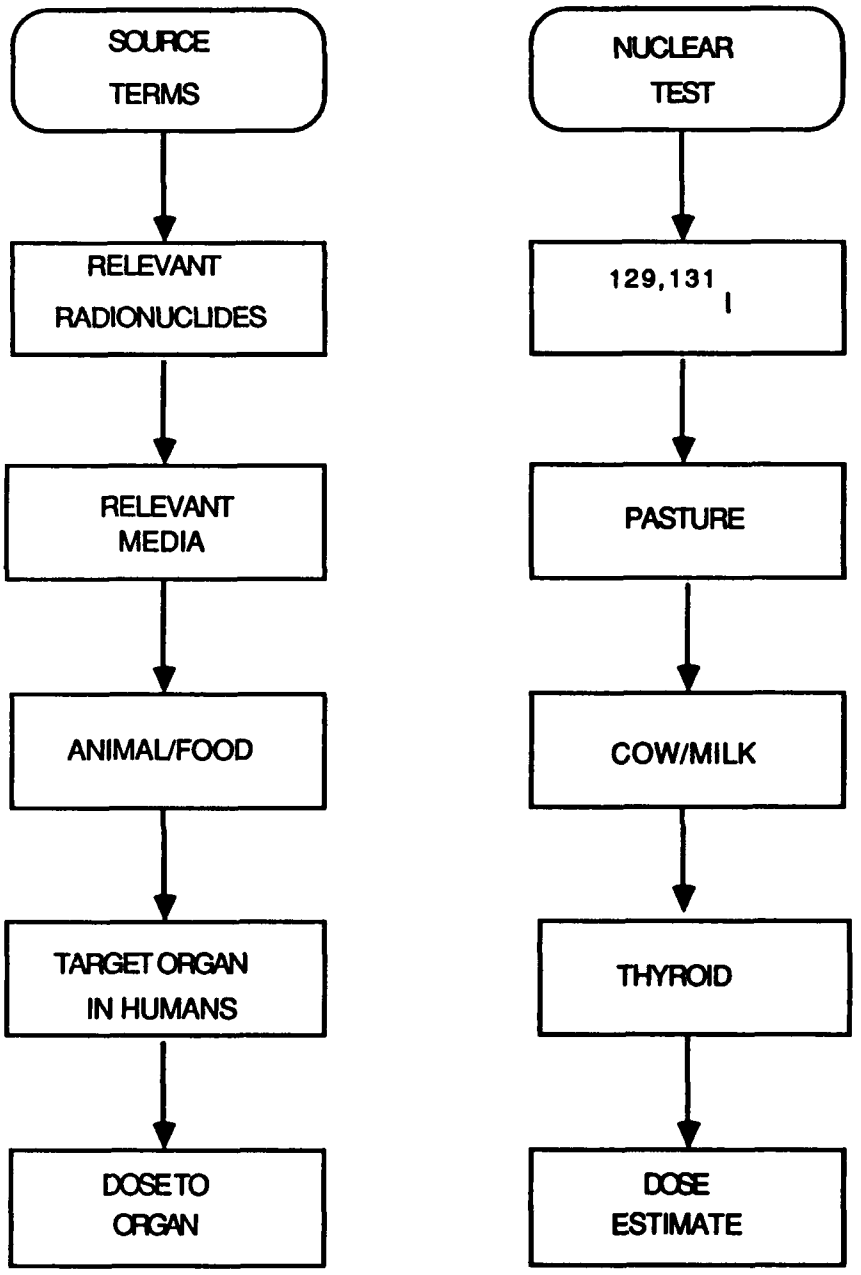


Figure 19. Basic elements of the model structure for retrospective dosimetry for ^{129}I and ^{131}I from nuclear weapons tests: left, relevant compartment of the model; right, specific compartments considered.

3.3 ENVIRONMENTAL AND DOSIMETRIC MODEL FOR RADIONUCLIDES

3.3.1 Source Terms.

One can consider as a starting point a single event (or shot) in which the accumulation of radioiodines in milk, through the simplified pathway pasture → cow/milk, reaches a maximum level and then decays exponentially to a very low level. The residual ^{129}I activity concentration in a thyroid at a time t after the event indicates the amount of shorter lived radioiodines also present in the thyroid at the same time t. Interpreting the time t as the time elapsed between the occurrence of the event and the death of the exposed individual, one can calculate an activity ratio $\lambda N_{129}(t)/\lambda' N_{131}(t)$, where λ and λ' are the decay constants of ^{129}I and ^{131}I, respectively, and N_i for i=129 or 131 is the number of atoms of a nuclide with mass number i pertaining to a decay chain characterized by that mass number. The radioiodines ^{129}I, ^{131}I, and ^{133}I, the latter with a half-life of only 20.8 hours, are those that can be transferred to milk. All other radioiodines have half-lives too short to be accumulated by the pathway considered in the model.

The radioiodine atom ratio N/N', with N and N' denoting the number of atoms of ^{129}I and ^{131}I, respectively, should, in principle, be related with the fission yields, FY, for the 129 and 131 decay chains by the expression in Equation 3-1:

$$N/N' = FY(129) / FY(131) \qquad (3\text{-}1)$$

The fission chains that produce the radioiodines ^{131}I and ^{129}I are represented in Figures 20 and 21, respectively, based on data taken from the literature (Ref. 29). Only 1% of ^{131}I is produced directly from the primary fission while the remaining 99% ^{131}I is formed by the decay chain shown in Figure 20. The fate of ^{131}I formed in an event depends, among other factors, on the size of the device and on the time-temperature conditions following the explosion, because the precursors of ^{131}I in the decay chain do not have half-lives longer than 30 hours. However, the ^{129}I decay chain shown in Figure 21 has a 17% branching ratio, which leads to the 34 days half-life of ^{129m}Te, which is a "stopper" in this decay chain.

Taking into account the data shown in Figure 20 and 21 for the decay chains 131 and 129, one can write a time-dependent ratio N(t)/N'(t) as Equation 3-2:

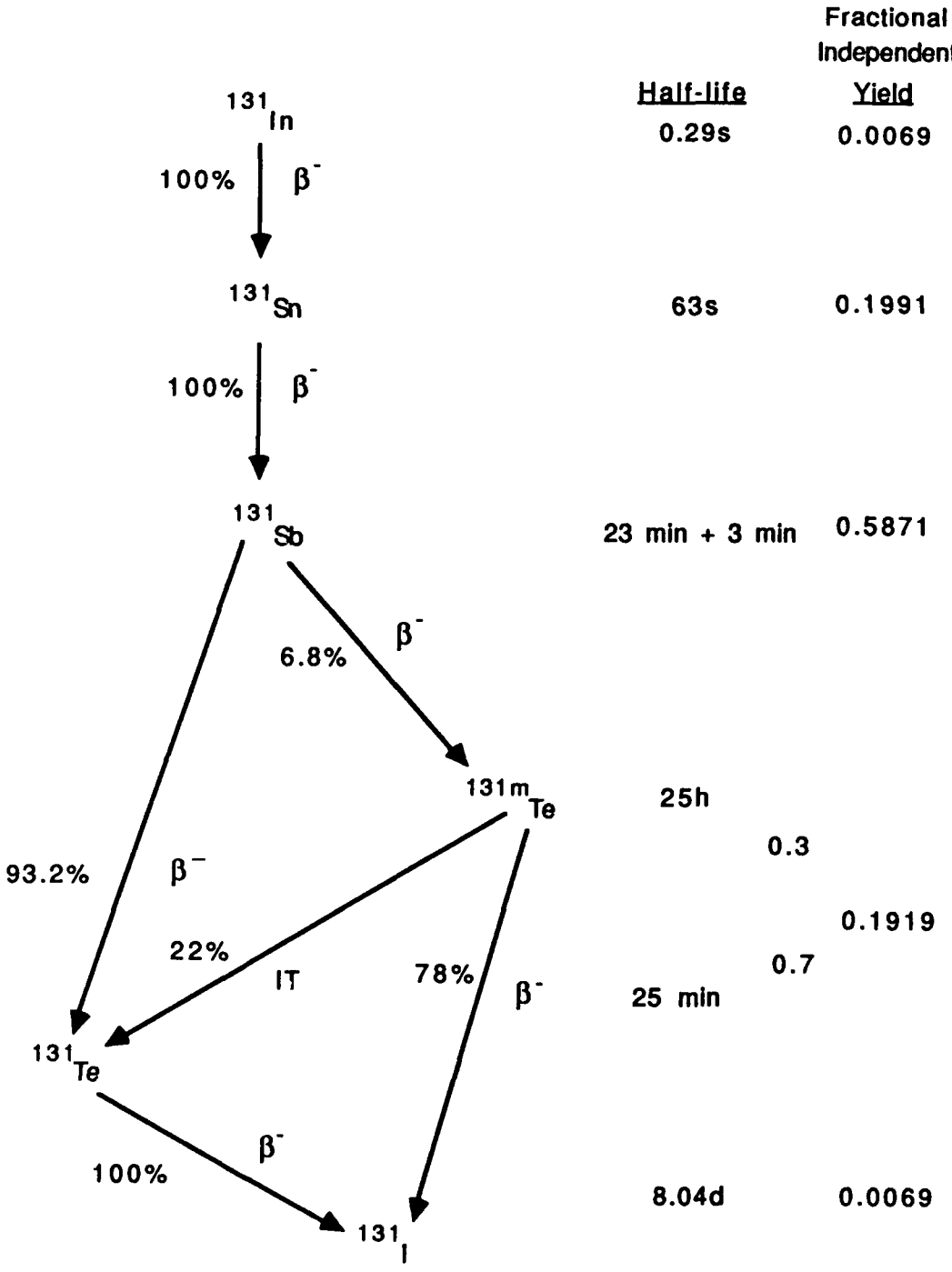


Figure 20. Fission decay chain of mass number 131.

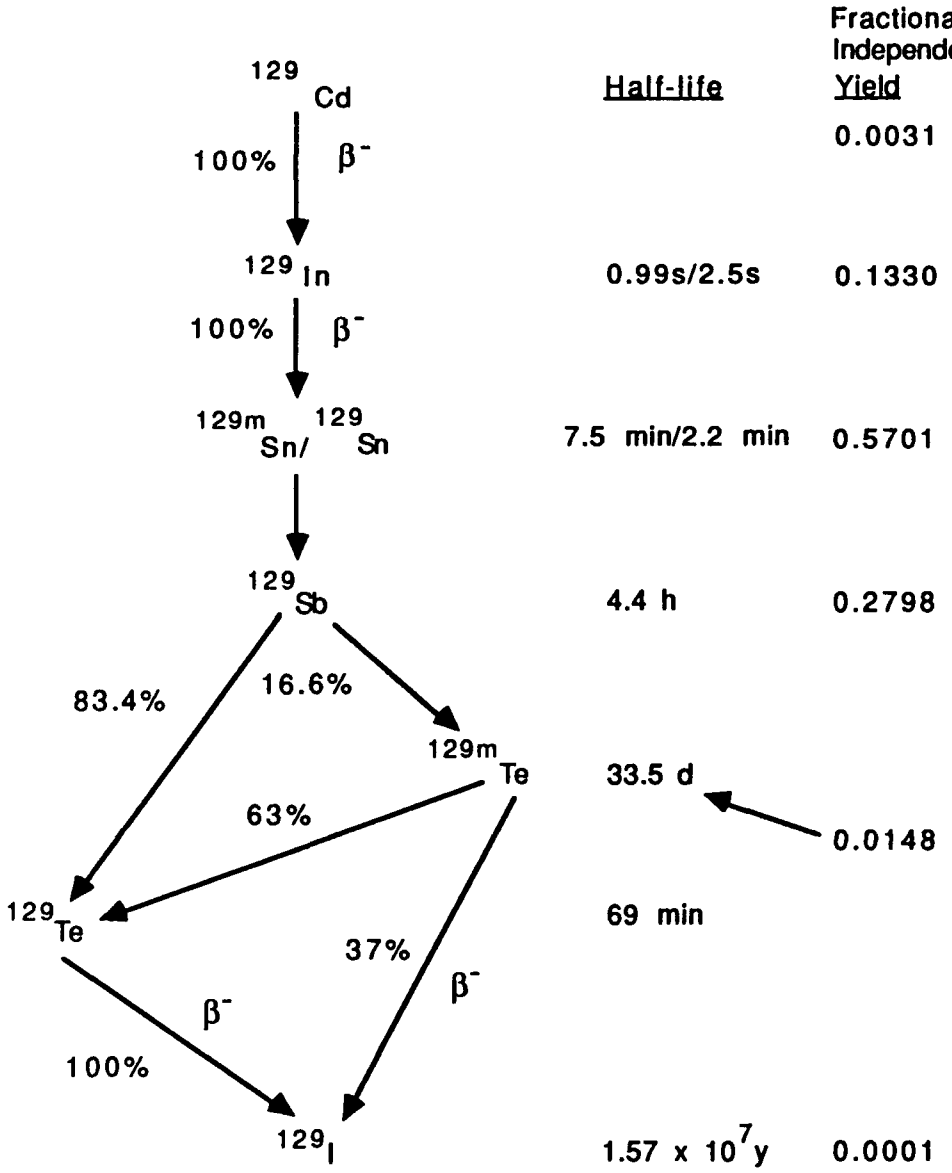


Figure 21. Fission decay chain of mass number 129.

$$\frac{N(t)}{N'(t)} = \frac{0.83N_{129}(365)e^{-\lambda(^{129}I)t} + 0.17N_{129}(365)[1-e^{-\lambda(^{129m}Te)t}]}{N_{131}(0)e^{-\lambda(^{131}I)t}} \qquad (3\text{-}2)$$

where 365 means 365 d (=1y), which is used here because it is a time longer than ten ^{129m}Te half-lives of 34 d.

However, since the relevant ratio for the model is N(0)/N'(0), one can easily determine from Equation 3-2, for t = 0 that Equation 3-3 reads:

$$N(0) = 0.83\ N_{129}(365) \qquad (3\text{-}3)$$

Using now the proportionality between the fission yield of a specific mass number, and the number of atoms of that mass number, one can write Equation 3-4:

$$\frac{N(0)}{N'(0)} = 0.83\ \frac{FY(129)}{FY(131)} \qquad (3\text{-}4)$$

Examining the decay chain shown in Figure 21, one notices that the nuclide starting the branching ratio in the 129 decay chain is ^{129}Sb, 4.4 h half-life, while the nuclide preceding the branching ratio in the 131 decay chain, shown in Figure 20, is ^{131}Sn, 63 s half-life. In addition, there are not any "stoppers" in the 131 chain to the beta decay up to ^{131}I. As a consequence, one cannot actually claim that the ratio N(0)/N'(0) is 83% of the ratio of the fission yields of these two decay chains, because the meaning of N(0) is somewhat elusive because of the "stoppers" in the 129 decay chain. Despite this interpretive detail, when considering the preceding equation, the time-dependent activity ratio can be written as Equation 3-5:

$$\frac{A(^{129}I)}{A(^{131}I)} = 0.83\ \frac{\lambda FY(129)}{\lambda' FY(131)} \left\{ \frac{e^{-\lambda(^{129}I)t} + 0.205\ [1-e^{-\lambda(^{129m}Te)t}]}{e^{-\lambda(^{131}I)t}} \right\} \qquad (3\text{-}5)$$

The initial activity ratio can now be expressed by substituting t = 0 into Equation 3-6:

$$\frac{A(^{129}I)}{A(^{131}I)} = 0.83\ \frac{\lambda FY(129)}{\lambda' FY(131)} \qquad \text{for } t = 0 \qquad (3\text{-}6)$$

The numerical values for the decay constants, half-lives (Ref. 29) and fission yields (Ref. 28) for ^{131}I and ^{129}I are listed in Table 10.

An alternative way to obtain a time-dependent activity ratio A (^{129}I)/A(^{131}I) is to integrate a system of differential equations expressed as Equations 3-7a through 3-7d below (Ref. 8):

$$\frac{dN_3}{dt} = -\lambda_3 N_3 \tag{3-7a}$$

$$\frac{dN_4}{dt} = F_{34}\,\lambda_3 N_3 - \lambda_4 N_4 \tag{3-7b}$$

$$\frac{dN_5}{dt} = F_{35}\,\lambda_3 N_3 + F_{45}\,\lambda_4 N_4 - \lambda_5 N_5 \tag{3-7c}$$

$$\frac{dN_6}{dt} = \lambda_5 N_5 + F_{46}\,\lambda_4 N_4 - \lambda_6 N_6 \tag{3-7d}$$

where N_3, N_4, N_5, and N_6 are the number of atoms of Sb, ^{m}Te, Te, and I, respectively, for the 129 and 131 decay chains; λ_i, i = 3 to 6 are the decay constants; and F_{ij}, i = 3 to 6, and j = 4 to 6 are the branching ratios.

The initial conditions to integrate equations 3-7a through 3-7d are given in Equations 3-8a through 3-8d:

$$N_3(0) = Y_1 + Y_2 + Y_3 \tag{3-8a}$$

$$N_4(0) = Y_4 \tag{3-8b}$$

$$N_5(0) = Y_5 \tag{3-8c}$$

$$N_6(0) = Y_6 \tag{3-8d}$$

where 1,2,3,4,5, and 6 denote In, Sn, Sb, ^{m}Te, Te, and I respectively, and Yi, i = 1 to 6 are the fractional independent yields.

The graph representing the time-dependent activity ratio A(^{129}I)/A (^{131}I) obtained with Equation 3-5 is represented in Figure 22, denoted by the Roman numeral I, together with the same ratio obtained by integrating Equations 3-7a through 3-7d using the same parameters used in Equation

3-5, the latter curve being identified by the Roman numeral II. There is no noticeable difference between the two curves shown in Figure 22 for times longer than about one day. Figure 23 represents the same graphs presented in Figure 22, but for t < 2d to show that only for times shorter than about 15 hours there is any noticeable difference between the two graphs.

When the numerical values listed in Table 10 are substituted into Equation 3-6, the activity ratio at time zero (i.e., for a time longer than 15 hours but not exceeding a couple of days) is about 7.5×10^{-10}. This activity ratio is also the ratio of concentrations of the radioiodines ^{129}I and ^{131}I expected to be found in vegetation.

3.3.2 Pasture.

The radioiodine activity ratio $^{129}I/^{131}I$ expected to be found in vegetation at a time "zero" (i.e., a time between 15 hours until about 2 days after the event) due to fallout, can be expressed as Equation 3-9:

$$\frac{A(^{129}I)}{A(^{131}I)} = \frac{C(0)}{C'(0)} \qquad (3\text{-}9)$$

where the left hand side of the expression is given by Equation 3-6 and C(0) and C'(0) are the radioiodine concentrations in the vegetation (in $Bq.kg^{-1}$ or $pCi.g^{-1}$) due to fallout at a time "zero" for ^{129}I and ^{131}I, respectively.

The time-dependent expressions for the concentrations of radioiodine in the vegetation are the following Equations 3-10 and 3-11:

$$C(t) = C(0)\, e^{-\lambda_v t}, \qquad \text{for } ^{129}I \qquad (3\text{-}10)$$

$$C'(t) = C'(0)\, e^{-\lambda'_v t}, \qquad \text{for } ^{131}I \qquad (3\text{-}11)$$

where: λ_v and λ'_v are the effective decay constants in vegetation for ^{129}I and ^{131}I, respectively, including radioactive decay and losses from rain, wind, etc.

Numerical values for λ_v and λ'_v are given in Table 11 with other decay constants to be used in the model.

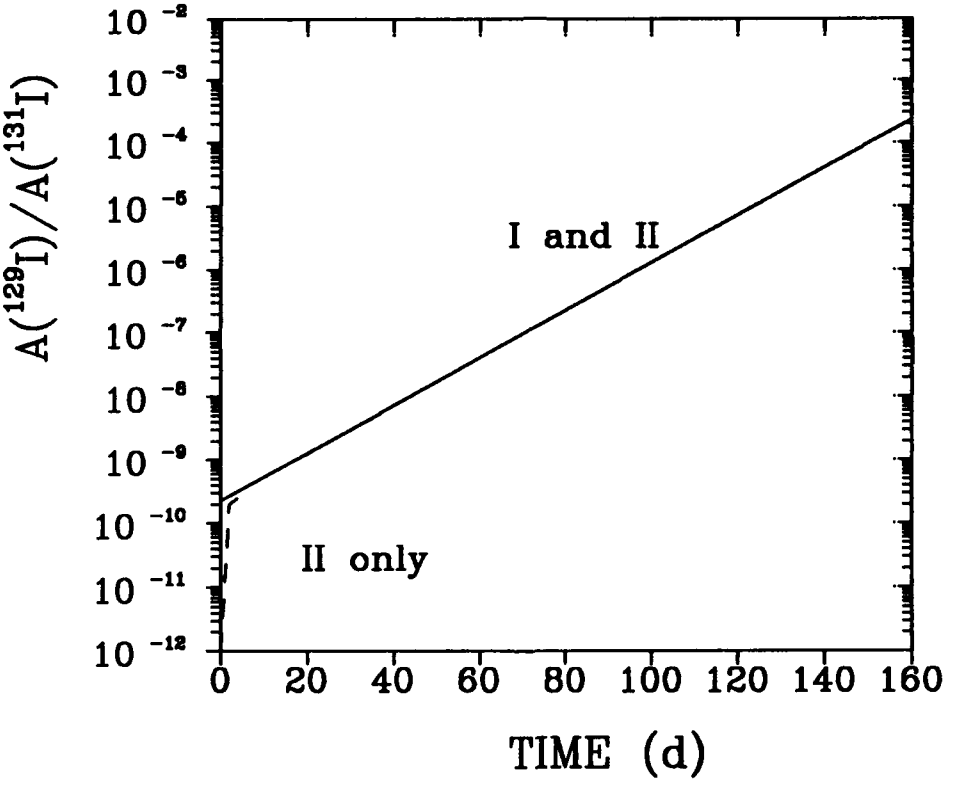


Figure 22. Graphs of the time-dependent activity ratio $A(^{129}I)/A(^{131}I)$: curve I is the representation of Eqn. (3-5) and curve II represents the equation obtained by integrating the differential Eqn. (3-7) under the initial conditions given by Eqn. (3-8).

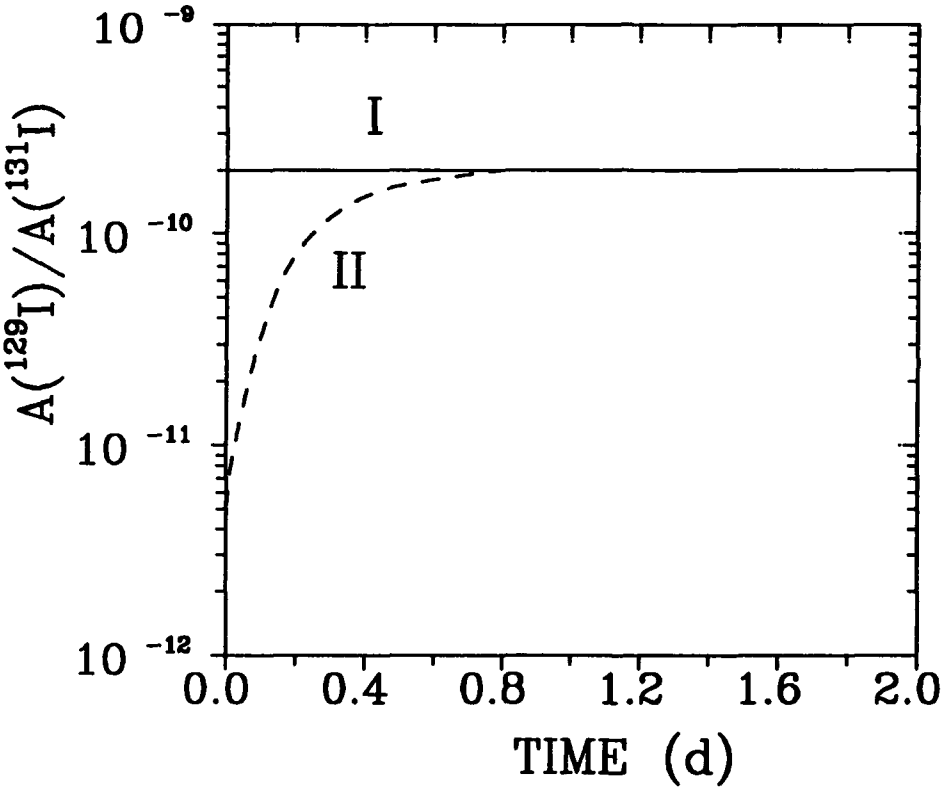


Figure 23. Expanded view of the graphs shown in Figure 5 for a time interval between zero and 2 d.

Table 10. Relevant physical parameters of ^{131}I and ^{129}I: Fission Yields (FY); half-lives ($T_{1/2}$) and decay Constants (λ).

Chain	FY*	RADIOIODINE Symbol	$T_{1/2}$	$\lambda(d^{-1})$
131	0.036	^{131}I	8.04 d	8.62×10^{-2}
129	0.0062	^{129}I	1.6×10^{7}y	1.20×10^{-10}

*$^{129}FY/^{131}FY$ = 0.24 above, whereas, using shot Harry as a surrogate for all tests, the ratio inferred from Hicks (Hi 81) is 0.17.

Table 11. Decay constants for ^{131}I and ^{129}I.

Meaning of Subscript	Subscript i	$\frac{^{131}I}{\lambda'_i(d^{-1})}$	$\frac{^{129}I}{\lambda_i(d^{-1})}$
Physical	--	8.62×10^{-2}	1.20×10^{-10}
Vegetation*	V	1.39×10^{-1}	5.33×10^{-2}
Milk	M	3.65×10^{-1}	2.77×10^{-1}
Human Thyroid	T	9.12×10^{-2}	6.93×10^{-3}

* This decay constant includes radioactive decay, loss due to rain, wind, etc.

3.3.3 Cow/milk.

The radioiodine (either ^{131}I and ^{129}I, in this case) deposited by fallout on the vegetation (pasture compartment) is transferred to the cow/milk compartment through ingestion, and then bovine metabolism. The rate of change of radioiodine activity concentration in the milk dI_m/dt can be expressed as Equation 3-12 (Ref. 18):

$$\frac{dI_m}{dt} = \frac{Gf_m}{V} C(t) - I_m \lambda_m \qquad (3\text{-}12)$$

where G is the cow's consumption of vegetation (in $g.d^{-1}$), V is the cow's milk production rate (in $L.d^{-1}$), C(t) is given either by Equation 3-10 or 3-11, depending on the radioiodine, f_m is the fraction of radioiodine ingested which goes into milk, λ_m is the "observed" effective decay constant in milk (in d^{-1}) for the radioiodine in question (^{129}I or ^{131}I).

Integrating Equation 3-12, one obtains:

$$I_m(t) = \frac{Gf_m C(0)}{(\lambda_m - \lambda_v) V} (e^{-\lambda_v t} - e^{-\lambda_m t}) \qquad (3\text{-}13)$$

where the numerical values of the decay constants are given in Table 11 and a list of nominal values for G, f_m, V, and C(0) are presented in Table 12 with other parameters.

For reasons of convenience, Equation 3-13 can be re-written as Equation 3-14:

$$I_m(t) = I_0 (e^{-\lambda_v t} - e^{-\lambda_m t}) \qquad (3\text{-}14)$$

with:

$$I_0 = \frac{Gf_m C(0)}{(\lambda_m - \lambda_v) V} \qquad (3\text{-}15)$$

It is interesting to note here that $I_o \neq I_m(0)=0$. (See Ref. 33 for sensitivity analysis.)

A test for the adequacy of the numerical values of decay constants λ_v and λ_m can be made by calculating the time t_{max} corresponding to the maximum radioactive activity concentration in milk, and then normalizing Equation 3-14 by $I_m(t_{max})$.

The time t_{max} is expressed by Equation 3-16:

$$t_{max} = \frac{\ln \lambda_m - \ln \lambda_v}{\lambda_m - \lambda_v} \tag{3-16}$$

and Equation 3-14, when normalized, can be written as Equation 3-17:

$$\frac{I_m(t)}{I_m(t_{max})} = \frac{e^{-\lambda_m t} - e^{-\lambda_v t}}{e^{-\lambda_m t_{max}} - e^{-\lambda_v t_{max}}} \tag{3-17}$$

Table 13 lists the values for t_{max} for ^{131}I and ^{129}I based on decay constants given in Table 11. The adequacy of the values of λ'_v and λ'_m, for ^{131}I, has been tested with favorable results, using data obtained from the Chernobyl accident (Ref. 26).

Figure 24 shows graphs of Equation 3-17 for ^{129}I and ^{131}I. One can see from Figure 24 that there is a residual ^{129}I activity in milk long after the ^{131}I activity has practically disappeared.

The ^{129}I residual activity can even be enhanced when soil resuspension, root uptake, and soil ingestion are also taken into account in the transfer of ^{129}I to the cow/milk compartment. Figure 25 illustrates a compartmental model, including soil resuspension as one of the transfer routes. A time-dependent soil resuspension factor $F_s(t)$ can be introduced to multiply the first term of the right hand side of Equation 3-12 together with an activity transfer coefficient f_{am} from soil to milk. The expression for $F_s(t)$ can be expressed as Equation 3-18:

$$F_s(t) = \frac{S_{air}(t)}{S_s(t)} = K_1 e^{-\lambda_{s1} t} + K_2 e^{-\lambda_{s2} t} \tag{3-18}$$

where $S_{air}(t)/S_s(t)$ is the ratio of the ^{129}I activity concentration in air to soil, K_1 and K_2 are dimensionless constants, λ_{s1} and λ_{s2} are short- and long-term decay constants for ^{129}I in soil, respectively.

A resuspension factor for ^{131}I does not need to be considered, because of the short half-life of this radioiodine. However, when compared with the radioiodine in the vegetation, soil resuspension, root uptake, and soil consumption should not contribute significantly to the transfer of ^{129}I to milk, therefore, and in most cases, can be ignored. The present model does not incorporate a

Table 12. Nominal parameters used in the pathways vegetation → cow/milk → human thyroid (data taken from Fr59).

Symbol	Numerical Value and Unit	Explanation
G	1.4×10^4 g.d^{-1}	Consumption rate of vegetation by animal
C_0	4.4 Bq ^{131}I.g^{-1} (1.2×10^2 pCi^{131}I.g^{-1})	^{131}I concentration in vegetation at t=0 due to fallout
V	10 L.d^{-1}	Milk production for each cow
M	1 L.d^{-1}	Milk consumption rate by humans
f_m	0.03	Fraction of radioiodine ingested which goes into milk
f_T	0.25	Fraction of radioiodine in milk which enters the human thyroid

Table 13. Times of maxima radioiodine concentrations for ^{131}I and ^{129}I in milk calculated by equation (3-16).

Radioiodine	t_{max}(d)
^{131}I	5.1
^{129}I	7.4

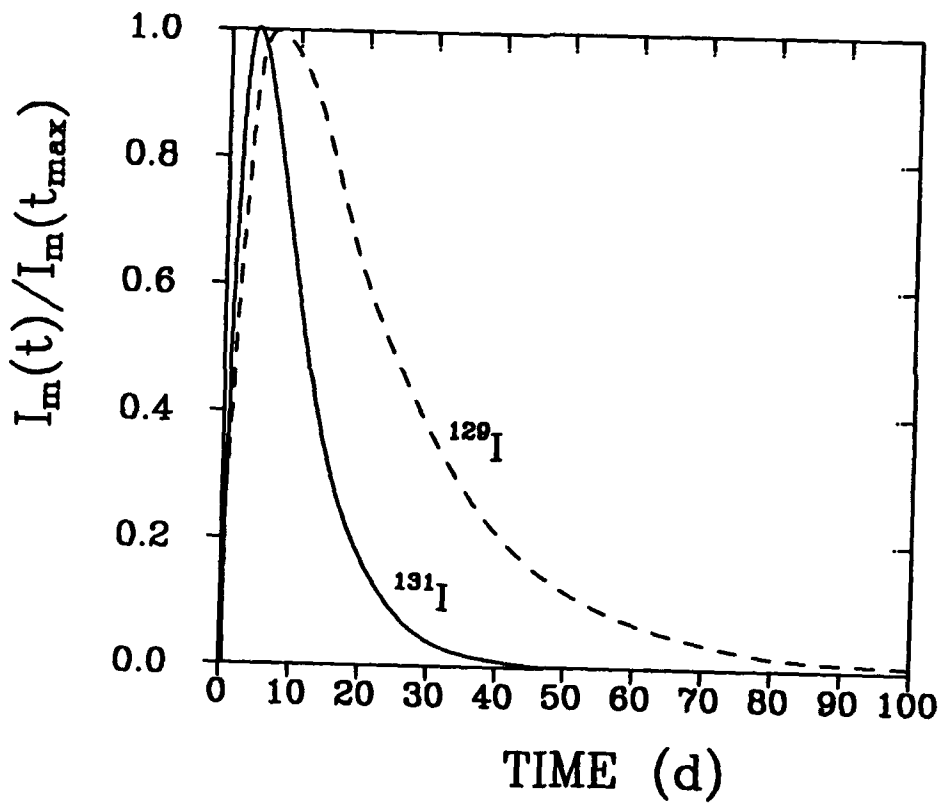


Figure 24. Graphs of the time-dependent activity ratio in milk $I_m(t)/I_m(t_{max})$ given by Eqn. (3-17) for ^{129}I and ^{131}I.

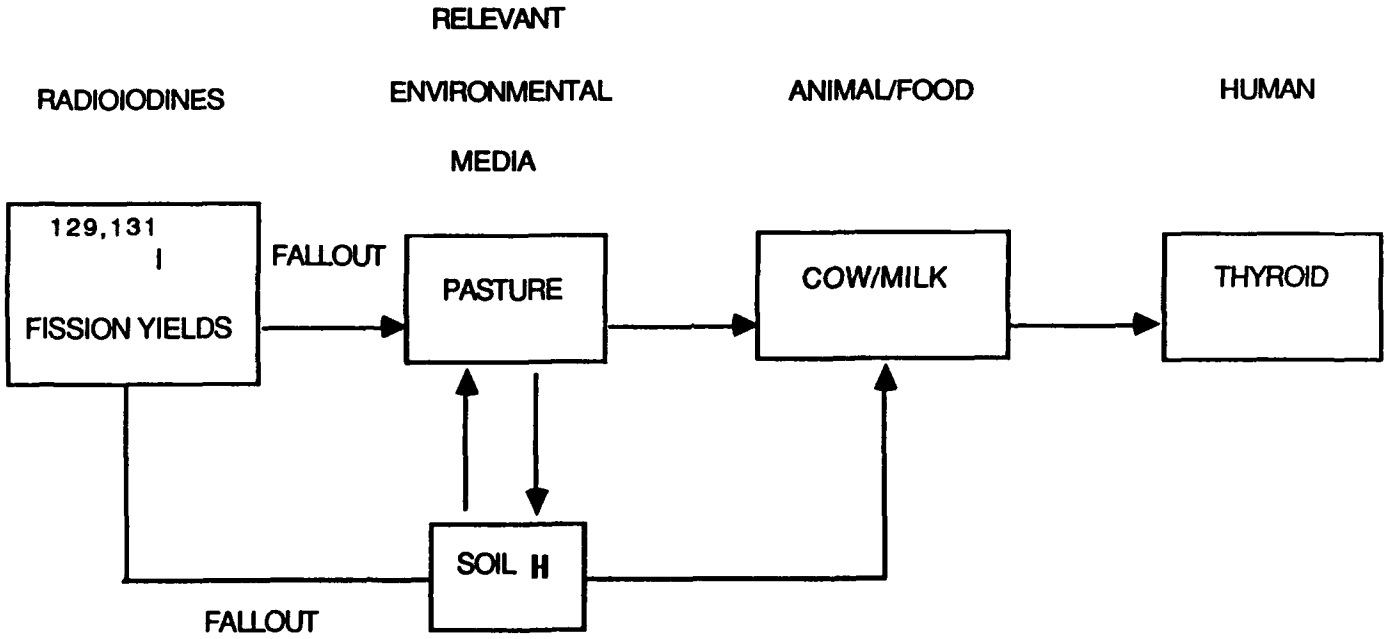


Figure 25. Modified model structure to include soil resuspension.

time-dependent factor for soil resuspension, as given in Equation 3-18, to avoid unnecessary calculational complications.

3.3.4 Human Thyroid.

The net radioiodine (either ^{131}I or ^{129}I in this case) intake by human thyroid from milk can be expressed by the following differential equation (Ref. 25):

$$\frac{dA_T}{dt} = I_0 M f_T (e^{-\lambda_v t} - e^{-\lambda_m t}) - \lambda_T A_T \qquad (3\text{-}19)$$

where A_T is the radioiodine activity in the thyroid at a time t (in Bq or pCi), M is the milk consumption rate by humans (in $L.d^{-1}$), f_T is the fraction of the radioiodine that enters the human thyroid, and λ_T is the radioiodine decay constant for the thyroid (in d^{-1}).

The numerical value of λ_T for ^{129}I or ^{131}I (λ'_T for ^{131}I) is given in Table 11, while nominal values for M and f_T are listed in Table 12.

Integrating Equation 3-19 one obtains:

$$A_T(t) = \frac{I_0 M f_T}{(\lambda_T - \lambda_m)(\lambda_T - \lambda_v)} \left[(\lambda_T - \lambda_m) e^{-\lambda_v t} + (\lambda_m - \lambda_v) e^{-\lambda_T t} - (\lambda_T - \lambda_v) e^{-\lambda_m t} \right] \qquad (3\text{-}20)$$

Figure 26 represents for illustrative purposes the time-dependent curve $A_T(t)$, with t in days up to 1000 d for ^{129}I, taking into account the numerical values for parameters given in Tables 11 and 12. One can clearly see from Figure 26 that ^{129}I in the thyroid is removed with a half-life of about 100 d, and consequently when an exposed person dies at about 300 d after an event, the ^{129}I activity remains about one order of magnitude lower than the maximum ^{129}I activity reached in the organ. For comparison purposes, graphs of $A_T(t)$ are also represented in Figure 27 for both radioiodines ^{131}I and ^{129}I. One can see in Figure 27 that although the maximum ^{131}I activity in the thyroid is more than 10^6 times the maximum ^{129}I, after about 210 d the ^{129}I activity in the organ becomes larger than the ^{131}I activity.

The ^{129}I content of a thyroid can be measured by means of neutron activation of stored thyroid blocks of individuals who died at times even longer than one year after an event. After death, the ^{129}I in the thyroid decays with the physical half-life of 1.6×10^7 y, therefore, the ^{129}I in the

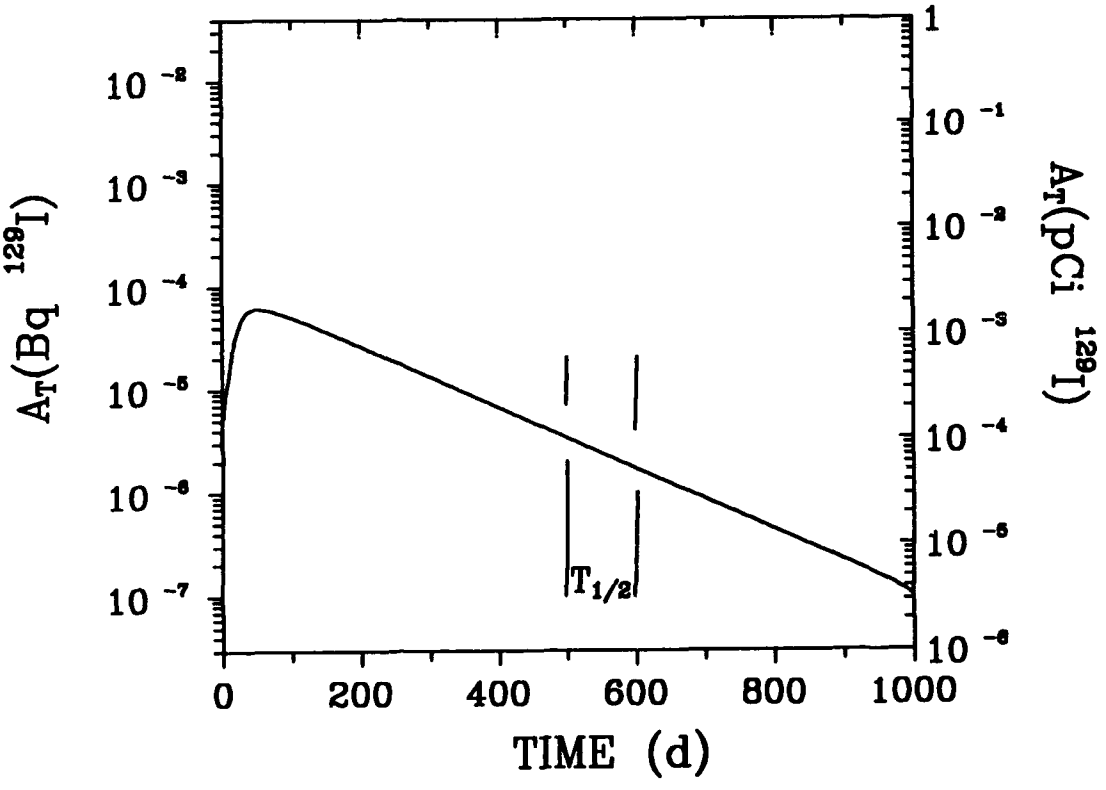


Figure 26. Graph of the time-dependent ^{129}I activity in the thyroid for a time interval $0 < t < 1000$ d.

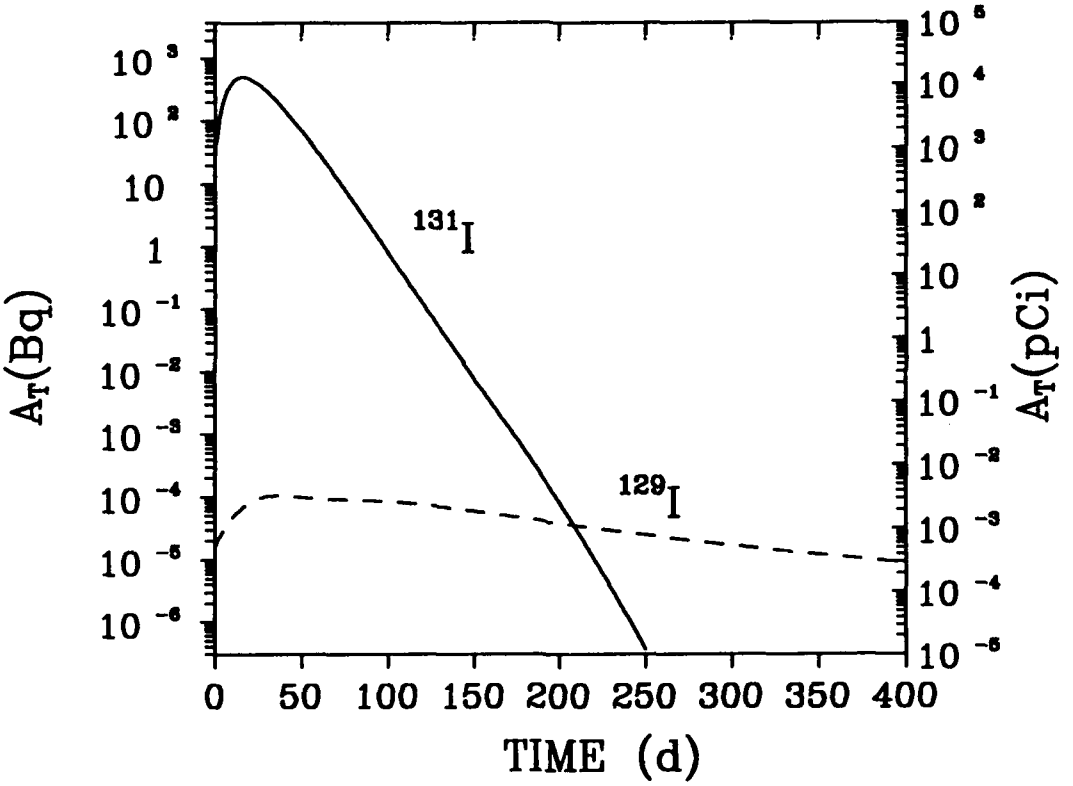


Figure 27. Graphs of the time-dependent activities of ^{129}I and ^{131}I in the thyroid for a time interval $0 < t < 400$ d.

thyroid blocks measured at the present time corresponds essentially to the same ^{129}I content that could have been measured at time of death.

3.4 DOSE TO THE THYROID.

The relevant quantity for calculating retrospectively the dose commitment D_c to the thyroid is the time integrated ^{131}I activity in this organ from a time zero (marking the beginning of the accumulation of ^{131}I in the thyroid) up to a time t after the event, considered here as the time of death of the individual. This relevant quantity can be called the cumulative (or time integrated) ^{131}I activity in the thyroid and denoted Cum(^{131}I) and the expression for Cum(^{131}I) (see Ref. 33 for sensitivity analysis) is:

$$\text{Cum}(^{131}\text{I}) = \int_0^t A'_T(t)\,dt \qquad (3\text{-}21)$$

where $A'_T(t)$ is given by Equation 3-20 with the numerical values of pertinent parameters being those for ^{131}I given in Tables 11 and 12.

The relation between D_c and Cum(^{131}I) can be expressed as Equation 3-22:

$$D_c(^{131}\text{I}) = \frac{[\,F\,]}{[\,m_T\,]}\,\text{Cum}(^{131}\text{I}) \qquad (3\text{-}22)$$

where F is a dose factor (in $\frac{\text{Gy}}{\text{d}} / \frac{\text{Bq}\,^{131}\text{I}}{\text{g}}$ or $\frac{\text{rad}}{\text{d}} / \frac{\text{pCi}\,^{131}\text{I}}{\text{g}}$), and m_T is the mass of the thyroid.

Integrating Equation 3-21 and substituting Equation 3-22, one obtains:

$$D_c(^{131}\text{I}) = \frac{(F/m_T)\,I_0 M f_T}{(\lambda_v-\lambda_T)(\lambda_m-\lambda_T)}\left[\frac{(\lambda_v-\lambda_T)}{\lambda_m}(1-e^{-\lambda_m t}) + \frac{(\lambda_m-\lambda_v)}{\lambda_T}(1-e^{-\lambda_T t}) - \frac{(\lambda_m-\lambda_T)}{\lambda_v}(1-e^{-\lambda_v t})\right] \qquad (3\text{-}23)$$

The retrospective dose commitment $D_c(^{131}I)$ given by Equation 3-23 corresponds to the dose due to the integrated activity, represented by the area under the curve for ^{131}I shown in Figure 27, from the approximate time of the event until the time of death. When the time of death is not known, an upper limit can be established for $D_c(^{131}I)$ by making $t\rightarrow\infty$. This upper limit is expressed as:

$$D_{c\,max}(^{131}I) = \frac{(F/m_T)\,I_0 M\,f_T}{(\lambda_v - \lambda_T)(\lambda_m - \lambda_T)} \left[\frac{(\lambda_v - \lambda_T)}{\lambda_m} + \right.$$

$$\left. + \frac{(\lambda_m - \lambda_v)}{\lambda_T} - \frac{(\lambda_m - \lambda_T)}{\lambda_v} \right] \qquad (3\text{-}24)$$

The dose factor F is determined by taking into account the unit activity concentration of ^{131}I to calculate a dose rate. Thus, one can write Equation 3-25 (See, for example, Ref. 16):

$$1\,pCi^{131}I = \frac{(2.22\ dis.min^{-1})\ (\ 0.189\ MeV.dis^{-1})\ (1.6x10^{-6}erg.MeV^{-1})}{100\ erg/g/rad}\ x \qquad (3\text{-}25)$$

$$x\ (1.440 \times 10^{3} min.d^{-1}) \quad = 9.7 \times 10^{-6} \quad rad.d^{-1}$$

or in Bq and Gy units (i.e., in units of the international systems-SI),

$$1\,Bq^{131}I = \frac{(1\ dis.s^{-1})\ (\ 0.189\ MeV.dis^{-1})\ (1.6x10^{-6}erg.MeV^{-1})}{(100\ erg/g/rad)\ (100\ rad/Gy)}\ x \qquad (3\text{-}26)$$

$$x\ (8.64 \times 10^{4} s.d^{-1}) \quad = 2.6 \times 10^{-6}\ Gy.d^{-1}$$

Thus, the dose factor F can either be:

$$F = 9.7 \times 10^{-6}\ (rad.d^{-1}) / (pCi^{131}I) \qquad (3\text{-}27)$$

or:

$$F_{sI} = 2.6 \times 10^{-6}\ (Gy.d^{-1}) / (Bq^{131}I) \qquad (3\text{-}28)$$

The thyroid mass m_t for an adult according to ICRP Publication 23 (Ref. 23) is considered to be $m_t = 20$ g.

One has to consider that in cases of retrospective dosimetry, a time sufficiently long has elapsed since the death of the individual, so that ^{131}I activity in the thyroid cannot be detected. Thus, the only measurable quantity available to evaluate the radioiodine incorporation due to an event s the ^{129}I activity in the stored thyroid blocks. This measurable activity is given by $A_T(t)$, expressed by

Equation 3-20, when all numerical values for the pertinent parameters are those for ^{129}I given in Tables 11 and 12.

The curve representing Equation 3-20 for ^{129}I is shown in Figure 26. The activity $A_T(t)$ for ^{129}I measured at the present time is essentially the same present at time of death, because the half-life of ^{129}I is 1.57×10^7y. Thus, by measuring A(t) for ^{129}I present in a thyroid tissue block stored for a long time, the ^{129}I activity at time of death is also known, and the dose commitment $D_c(^{131}I)$ from the ^{131}I produced in the same event can be inferred by the knowledge of the quotient in Equation 3-29:

$$Q = \frac{A_T/m_T}{D_c} \tag{3-29}$$

where A_T is given by Equation 3-20 for ^{129}I for a time t corresponding to the interval between the event and the time of death, and D_c is given by Equation 3-23 for the same time interval.

The expression for the quotient Q is more conveniently written when one simplifies the common factors and parameters that appear in the expressions for A_T and D_c given by Equations 3-20 and 3-23, respectively. Thus, after simplifying, one can write Equation 3-30:

$$Q = \frac{C(0)}{FC'(0)} \frac{(\lambda'_m - \lambda'_v)\ (\lambda'_T - \lambda'_m)\ (\lambda'_v - \lambda'_T)}{(\lambda'_m - \lambda'_v)\ (\lambda'_T - \lambda'_m)\ (\lambda'_v - \lambda'_T)} \times$$

$$\times \frac{\left[(\lambda_T - \lambda_m)e^{-\lambda_v t} + (\lambda_m - \lambda_v)e^{-\lambda_T t} - (\lambda_T - \lambda_v)e^{-\lambda_m t}\right]}{\left[\frac{(\lambda'_v - \lambda'_T)}{\lambda'_m}(1-e^{-\lambda'_m t}) + \frac{(\lambda'_m - \lambda'_v)}{\lambda'_T}(1-e^{-\lambda'_T t}) - \frac{(\lambda'_m - \lambda'_T)}{\lambda'_v}(1-e^{-\lambda'_v t})\right]} \tag{3-30}$$

where F is given by Equation 3-27 or by Equation 3-28, if the SI unit system is to be used -- the ratio C(0)/C'(0) was established by Equations 3-6 and 3-9, and the decay constants are given in Table 11.

One can consider that, in accordance with ICRP Publication 23 (Ref. 23), there is 0.6 mg of stable iodine (i.e., ^{127}I) per gram of thyroid. Thus:

$$\frac{1\ \text{Bq}\ ^{129}I}{\text{g thyroid}} = \frac{1\ \text{Bq}\ ^{129}I.\text{g}^{-1}\ \text{thyroid}}{0.6\text{mg}\ ^{127}I.\text{g}^{-1}\ \text{thyroid}} = \frac{1.7\ \text{Bq}\ ^{129}I}{\text{mg}\ ^{127}I} \tag{3-31}$$

and the activity concentration A_T/m_T of ^{129}I given by Equation 20 can be expressed in (Bq ^{129}I)/(mg $^{127}I)^{-1}$ rather than in (Bq ^{129}I).g^{-1} thyroid (or in pCi $^{129}I.g^{-1}$ ^{127}I rather than by pCi $^{129}I.g^{-1}$ thyroid).

$$\frac{1\ pCi\ ^{129}I}{g\ thyroid} = \frac{1\ pCi\ ^{129}I.g^{-1}\ thyroid}{0.6mg\ ^{127}I.g^{-1}\ thyroid} = \frac{1.7\ pCi\ ^{129}I}{mg\ ^{127}I} \qquad (3\text{-}32)$$

The time-dependent function 1/Q, corresponding to the inverse of Equation 3-30, allows one to know the retrospective dose commitment D_c (in Gy or rad) to the thyroid due to the cumulative ^{131}I activity Cum(^{131}I) in this organ, just by multiplying the numerical value of 1/Q at time of death by the ^{129}I activity concentration measured in a stored thyroid block. Figure 28 represents the time-varying function 1/Q in units of Gy·(Bq ^{129}I·mg^{-1} ^{127}I)$^{-1}$ or in rad·(pG·^{129}I·mg^{-1} ^{127}I)$^{-1}$. The ratio C(0)/C'(0) used in Equation 3-30, to make the graph of 1/Q represented in Figure 28, was obtained by substituting the numerical values for λs and FYs given in Table 10 into Equations 3-6 and 3-9. Thus the ratio C(0)/C'(0) used in Figure 28 was Equation 3-33:

$$\frac{C(0)}{C'(0)} = 2.0 \times 10^{-10} \qquad (3\text{-}33)$$

As a matter of fact, the results of the ^{129}I measurements in the stored thyroid blocks are reported in ^{129}I atoms/^{127}I atoms. Thus, one has to take into account that 1 Bq ^{129}I corresponds to 7.2 x 10^{14} ^{129}I atoms (or 1 pCi ^{129}I corresponds to 2.7 x 10^{13} ^{129}I atoms) and that 1 mg ^{127}I corresponds to 4.8 x 10^{19} ^{127}I atoms. Thus, the time-dependent function 1/Q needs to be divided by the factor represented in Equation 3-34:

$$\frac{1\ Bq\ ^{129}I}{mg\ ^{127}I} = 1.5 \times 10^{-5} \quad \frac{^{129}I\ atoms}{^{127}I\ atoms} \qquad (3\text{-}34)$$

$$\frac{1\ pCi\ ^{129}I}{mg\ ^{127}I} = 5.6 \times 10^{-7} \quad \frac{^{129}I\ atoms}{^{127}I\ atoms} \qquad (3\text{-}35)$$

to allow direct use of the reported results. Figure 29 represents the time-dependent function 1/Q expressed in units Gy/(^{129}I atoms/^{127}I atoms) or rad/(^{129} atoms/^{127}I atoms).

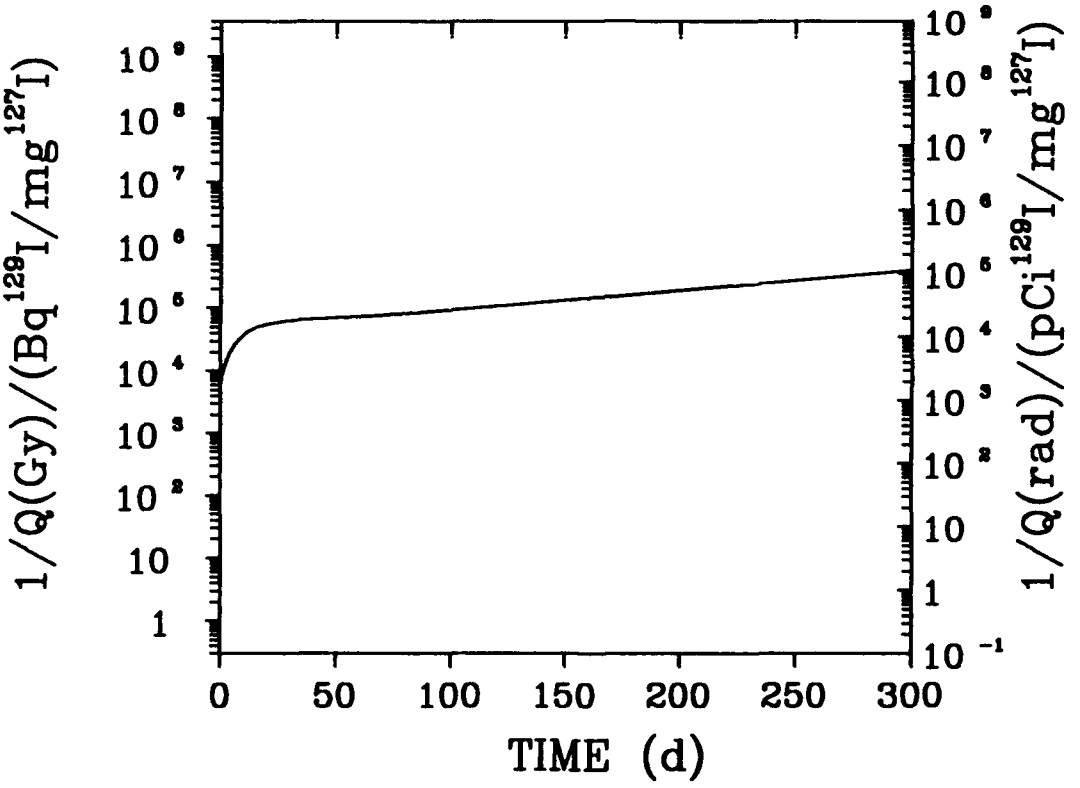


Figure 28. Graph of the 1/Q, with Q given by Eqn. 3-30 and expressed in units of Gy/(Bq^{129}I.mg^{-1} ^{127}I) or rad (pCi^{129}I.mg^{-1} ^{127}I).

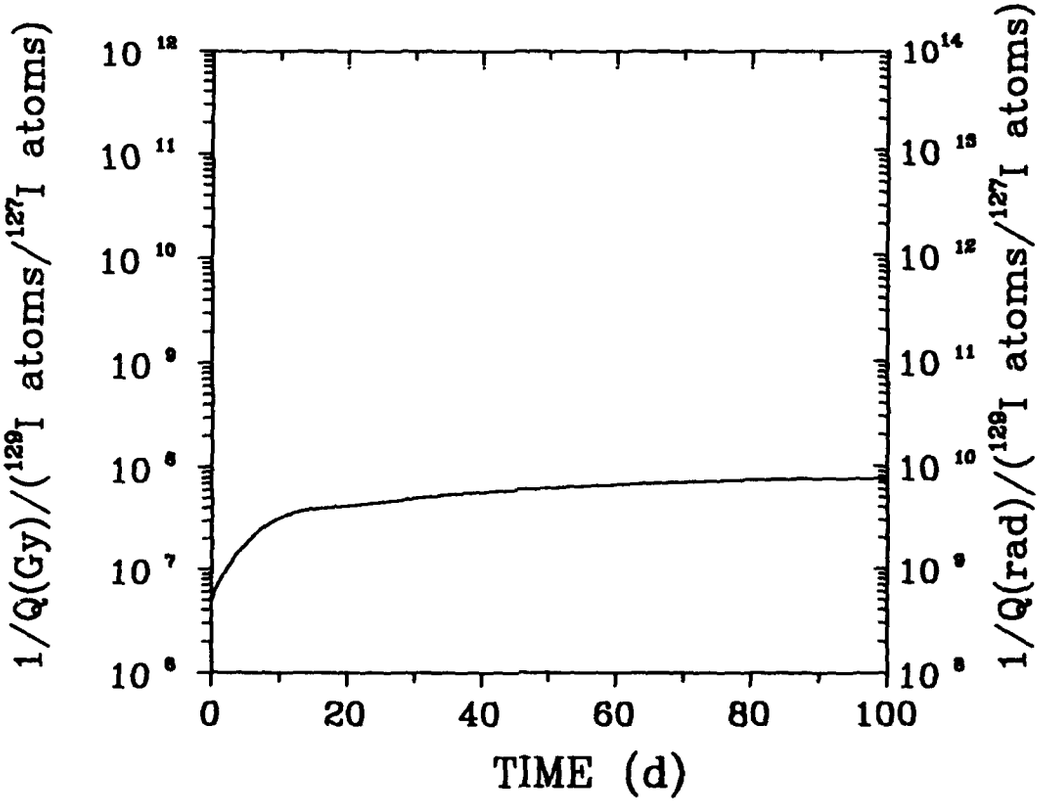


Figure 29. Graph of the time-dependent function 1/Q with Q given by Eqn. (3-30) and expressed in units of Gy/^{129}I atoms /^{127}I atoms) and in rad/(^{125}I atoms/^{127}I atoms).

3.5 CONCLUSIONS.

1. The retrospective dose commitment due to cumulative intake of ^{131}I by the thyroid can be estimated by the model described here, once one knows the following: the time elapsed between the death of the exposed individual and the detonation; and the measured atom ratio $^{129}I/^{127}I$ in the stored thyroid blocks.
2. The slope of the time-dependent curve 1/Q, represented in Figures 28 and 29, increases rapidly at the beginning, but the increase becomes gradual about 20 d after the event, eventually rising with a doubling time of 100 d.
3. The doubling time of 100 d in the 1/Q curve compensates the 100 d half-life of the effective ^{129}I removal rate in the thyroid as shown in Figure 26, emphasizing the need to know the time interval between the time of detonation (i.e., t = 0) and the time of death.
4. The effects on the model of the uncertainties associated with the correct time to be considered t = 0 and the correct fission yields are supposed to be unimportant when the local fallout occurred at times greater than 15 h after the actual time of detonation, but may be important for events when fallout occurred immediately following the detonation.
5. A solution for the common case of exposure to multiple detonations is not included in the current model, but can be obtained if the relative contributions of each detonation to ^{131}I milk can be assessed.

*

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SECTION 4
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APPENDIX A

MEASURED VALUES OF $^{239,240}Pu$ AND ^{238}Pu AND ^{234}U, ^{235}U AND ^{238}U IN TISSUES

Because of the computer program used to tabulate the data, results are tabulated to 2 decimal places. In some cases, this results in 5 digits, whereas only the second or third are significant.

The error terms are ± 1 standard deviation based only on counting statistics.

For ^{238}Pu, the counting error often exceeds the measured values, which are generally lower than the minimum detectable amounts (3σ).

Sample #	Tissue	Wet Weight (g)	Pu-239,240 mBq/kg wet	Pu-239,240 error mBq/kg wet
C09	Liver	403.43	43.66	2.96
C09	Lung	283.95	2.22	0.74
C09	Kidney	163.10	3.33	1.48
C09	Vertebrae	56.90	11.10	4.44
C09	Ribs	54.50	10.36	4.07
C09	Sternum	29.80	8.51	6.29
C10	Gonad	8.70	55.87	17.39
C10	Kidney	91.80	0.37	1.48
C10	L.N.	0.84	4.07	65.49
C10	Liver	328.15	5.18	1.11
C10	Ribs	50.00	1.11	5.18
C10	Spleen	97.20	2.96	1.48
C10	Thyroid	4.30	17.02	32.93
C10	Vertebrae	66.00	6.29	2.96
C11	Liver	263.90	48.84	2.59
C11	Lung	250.80	8.51	1.48
C11	Kidney	147.30	1.85	1.11
C11	Vertebrae	67.00	12.95	4.44
C11	Spleen	138.20	1.85	1.85
C11	Thyroid	9.40	12.21	8.51
C12	Liver	422.10	19.24	4.07
C12	Lung	209.53	4.81	1.85
C12	Kidney	161.00	2.22	1.48
C12	L.N.	5.60	-1.48	10.36
C12	Vertebrae	47.00	-4.44	2.96
C12	Ribs	64.00	1.85	2.59
C12	Sternum	93.20	7.77	3.70
C13	Vertebrae	37.00	10.36	5.92
C13	Ribs	68.00	8.51	3.33
C13	Sternum	59.80	7.77	2.59
C14	Liver	250.45	89.17	4.44
C14	Lung	251.90	25.90	2.96
C14	Kidney	168.20	0.74	0.37
C14	Spleen	232.80	5.55	1.11
C14	Vertebrae	83.00	8.51	2.96
C14	Gonad	19.20	-1.11	1.11
C14	L.N.	2.52	56.24	40.70
C14	Thyroid	12.60	0.74	2.96
C15	Vertebrae	47.00	0.74	1.85
C15	Ribs	16.00	1.85	5.18
C15	Sternum	40.00	1.85	2.59
C15	L.N.	0.50	84.73	285.27
C15	Thyroid	9.43	-6.66	14.06

Sample #	Tissue	Wet Weight (g)	Pu-239,240 mBq/kg wet	Pu-239,240 error mBq/kg wet
C15	Kidney	118.03	1.11	0.74
C15	Spleen	71.97	-1.48	6.66
C15	Liver	360.93		
C15	Lung	336.12	0.37	0.37
C16	Liver	240.07	2.22	0.74
C16	Lung	203.90	66.23	4.44
C16	Kidney	149.10	2.59	1.11
C16	L.N.	4.26	35.89	23.68
C16	Vertebrae	46.10	4.81	2.59
C17	Liver	485.90	2.22	0.74
C17	Lung	203.60	0.11	0.15
C17	Kidney	168.00	-42.18	0.74
C17	Spleen	298.70	0.15	0.74
C17	L.N.	1.71	29.97	38.11
C17	Gonad	26.20	-0.37	4.81
C17	Thyroid	14.40	-0.37	7.03
C17	Vertebrae	139.40	9.25	2.22
C18	Liver	280.18	9.62	1.85
C18	Lung	294.10	2.59	0.74
C18	Kidney	151.50	-0.07	1.11
C18	Spleen	187.30	1.48	0.74
C18	Thyroid	15.00	-8.51	11.84
C19	Liver	458.43	21.46	1.48
C19	Lung	290.65	2.22	0.74
C19	Kidney	148.00	0.07	1.11
C19	Spleen	166.30	4.44	1.11
C19	Thyroid	18.00	-0.37	7.03
C19	Gonad	31.40	13.32	8.88
C19	L.N.	5.70	-57.35	28.49
C19	Vertebrae	160.20		
C20	Liver	302.80	26.27	2.59
C20	Lung	264.45		
C20	Kidney	217.50	3.33	1.11
C20	Spleen	100.00	2.96	1.85
C20	Thyroid	15.90	6.66	5.18
C20	Gonad	15.10	9.99	7.03
C20	Ribs	41.10	11.47	4.44
C20	Vertebrae	101.70		
C20	Sternum	90.40	8.14	3.33
C21	Liver	670.00	6.66	0.74
C21	Lung	366.20	5.55	1.85
C21	Kidney	67.20	3.33	1.85
C21	Spleen	126.30	2.96	1.11

Sample #	Tissue	Wet Weight (g)	Pu-239,240 mBq/kg wet	Pu-239,240 error mBq/kg wet
C21	Thyroid	4.40	108.41	36.26
C21	Vertebrae	27.60	0.37	7.77
C22	Liver	290.30	8.88	1.11
C22	Lung	435.30		
C22	Kidney	140.00		
C22	Spleen	157.20	0.74	1.85
C22	Thyroid	14.70	20.72	12.21
C22	Gonad	62.30	-5.55	31.45
C22	Vertebrae	49.90	2.22	2.59
C22	L.N.	2.40	-77.70	166.50
C23	Liver	252.00	7.03	1.85
C23	Lung	300.90	0.19	0.37
C23	Kidney	160.70	-0.15	1.85
C23	Spleen	126.20	0.74	10.73
C23	Thyroid	22.90	-1.11	34.04
C23	Gonad	10.00	-33.30	33.30
C23	L.N.	4.90	11.10	44.40
C23	Vertebrae	175.30	4.07	1.85
82-N01	Liver	252.90	20.35	2.96
82-N01	Vertebrae	40.50	5.55	2.59
82-N02	Kidney	170.00	-0.37	-0.37
82-N02	Liver	1201.00	37.74	2.22
82-N02	Ribs	17.10	31.82	8.88
82-N02	Lung	412.40	1.48	1.11
82-N03	Kidney	169.50		
82-N03	Liver	1706.20	5.18	1.11
82-N03	Vertebrae	57.30	7.77	12.95
82-N04	Kidney	101.00	3.70	0.37
82-N04	Liver	451.90	11.47	0.74
82-N04	Ribs	33.50	18.87	1.48
82-N04	Vertebrae	46.70	6.29	8.14
82-N05	Kidney	64.70	0.37	-1.85
82-N05	Liver	524.10	2.59	2.22
82-N05	Vertebrae	66.80	19.24	3.33
82-N06	Kidney	158.20	0.37	0.74
82-N06	Liver	1450.80	11.10	0.37
82-N06	Lung	333.70	4.07	2.59
82-N06	Vertebrae	83.80	9.25	4.44
82-N07	Kidney	153.30	-0.74	-0.74
82-N07	Liver	323.50	29.97	5.55
82-N07	Lung	720.40		
82-N07	Ribs	31.40	30.34	-6.66
82-N07	Vertebrae	77.80	12.58	10.73

Sample #	Tissue	Wet Weight (g)	Pu-239,240 mBq/kg wet	Pu-239,240 error mBq/kg wet
82-N08	Kidney	130.14	1.48	0.37
82-N08	Liver	1699.00	37.37	1.85
82-N08	Lung	376.40	8.51	1.11
82-N08	Ribs	51.70	11.84	10.36
82-N08	Vertebrae	109.50	13.32	1.48
82-N09	Kidney	131.60	0.37	2.22
82-N09	Liver	325.80	15.91	4.44
82-N09	Lung	350.60	1.11	1.48
82-N09	Ribs	30.50	1.85	0.11
82-N09	Vertebrae	9.00	30.71	15.54
82-N10	Kidney	321.00	4.07	0.19
82-N10	Liver	567.30	30.34	4.44
82-N10	Lung	551.30	6.66	0.37
82-N11	Kidney	112.00	-1.11	-0.74
82-N11	Liver	158.20	30.71	4.07
82-N11	Lung	340.70	15.17	1.11
82-N11	Ribs	25.00	7.77	3.70
82-N11	Vertebrae	83.00	29.97	-0.37
82-N12	Kidney	286.00	0.74	-0.37
82-N12	Liver	227.00	25.90	0.37
82-N12	Lung	652.20		
82-N12	Ribs	68.00	1.85	1.85
82-N12	Vertebrae	74.00	0.74	2.59
82-N13	Kidney	156.00	-0.15	-1.11
82-N13	Liver	427.00	42.92	1.85
82-N13	Lung	762.00		
82-N13	Ribs	51.00	27.38	-1.48
82-N13	Vertebrae	60.00	11.10	-4.07
82-N14	Kidney	208.00	-0.04	-0.15
82-N14	Liver	503.00	41.81	1.48
82-N14	Ribs	35.00	28.12	2.22
82-N14	Vertebrae	65.00	9.25	-1.48
82-N15	Kidney	243.00	0.37	0.37
82-N15	Liver	292.00	41.81	2.22
82-N15	Lung	489.00	15.54	0.74
82-N15	Ribs	45.00	15.91	-0.74
82-N15	Vertebrae	61.00	11.10	2.59
82-N16	Kidney	141.00	1.48	-0.19
82-N16	Liver	692.00	41.81	1.85
82-N16	Lung	488.00	14.80	0.74
82-N16	Ribs	32.00	11.84	-1.85
82-N16	Vertebrae	107.00	9.62	-1.85
82-N17	Kidney	88.90	0.74	-1.48

Sample #	Tissue	Wet Weight (g)	Pu-239,240 mBq/kg wet	Pu-239,240 error mBq/kg wet
82-N17	Liver	244.60		
82-N17	Lung	237.00	-1.48	-0.15
82-N17	Ribs	36.00	-0.74	-1.48
82-N17	Vertebrae	81.00	1.11	-2.96
82-N18	Kidney	244.10	1.48	0.04
82-N18	Lung	279.30	5.18	-0.37
82-N18	Ribs	21.00	5.92	0.07
82-N18	Vertebrae	55.00	4.07	0.37
83-N19	Kidney	131.10	1.11	-0.37
83-N19	Liver	274.70	88.43	2.22
83-N19	Lung	569.20	12.21	0.74
83-N19	Ribs	33.00	5.92	-13.32
83-N19	Vertebrae	80.00	11.84	0.74
83-N20	Kidney	190.00	1.48	0.74
83-N20	Liver	192.10	5.18	-1.11
83-N20	Lung	297.60		
83-N20	Ribs	32.00	1.48	-0.15
83-N20	Vertebrae	59.00	7.03	-1.48
83-N21	Kidney	95.40	0.37	-1.11
83-N21	Liver	407.40	33.30	1.11
83-N21	Lung	112.20	11.84	1.11
83-N21	Ribs	24.50	9.62	-4.07
83-N22	Kidney	153.90	1.11	0.74
83-N22	Liver	576.00	9.25	0.74
83-N22	Lung	397.70	2.59	1.11
83-N22	Ribs	27.60	14.06	-0.74
83-N22	Vertebrae	74.70	0.37	2.22
83-N23	Heart	279.30		
83-N23	Kidney	227.90	1.11	-0.37
83-N23	Liver	279.90	35.52	1.85
83-N23	Lung	304.40	5.92	1.48
83-N23	Ribs	18.60	4.81	0.74
83-N23	Vertebrae	70.00	13.32	7.77
83-N24	Kidney	99.20	2.59	2.22
83-N24	Liver	186.80	72.15	14.80
83-N24	Lung	215.40	7.40	-0.07
83-N24	Ribs	27.20	7.40	14.06
83-N24	Vertebrae	79.80	12.21	0.37
83-N25	Kidney	100.00	11.10	5.55
83-N25	Liver	215.80	31.45	0.74
83-N25	Lung	194.05	1.48	0.74
83-N25	Ribs	50.00	0.74	0.74
83-N25	Vertebrae	46.60	4.07	2.59

Sample #	Tissue	Wet Weight (g)	Pu-239,240 mBq/kg wet	Pu-239,240 error mBq/kg wet
83-N26	Kidney	148.60	-1.11	-0.74
83-N26	Liver	336.20	9.62	3.70
83-N26	Lung	242.90	3.70	-0.37
83-N26	Ribs	16.50	45.14	20.35
83-N26	Vertebrae	35.70	5.92	-3.70
83-N27	Kidney	170.90	7.77	1.11
83-N27	Liver	196.70	21.83	0.37
83-N27	Lung	201.95	8.51	0.19
83-N27	Ribs	41.30	14.43	2.22
83-N27	Vertebrae	48.90	12.95	0.74
83-N28	Kidney	174.10	0.37	-0.74
83-N28	Liver	144.30	21.83	2.59
83-N28	Lung	327.90	1.48	-0.04
83-N28	Ribs	36.80	7.03	2.96
83-N29	Kidney	198.70	4.07	0.74
83-N29	Liver	381.60	168.35	11.84
83-N29	Lung	355.60	12.95	2.22
83-N29	Ribs	46.80	13.69	6.29
83-N29	Vertebrae	56.30	9.62	4.07
83-N30	Kidney	118.10	-1.11	-1.48
83-N30	Liver	182.70	44.77	1.11
83-N30	Lung	366.60	2.96	0.37
83-N30	Ribs	41.30	-15.17	-6.29
83-N30	Vertebrae	21.70	26.27	4.44
83-N31	Kidney	156.20	1.85	-0.74
83-N31	Liver	236.60	48.47	2.22
83-N31	Ribs	27.70	15.54	3.70
83-N31	Vertebrae	73.10	7.40	-1.11
83-N31	Lung	177.30	12.95	0.74
83-N32	Kidney	107.50	4.44	1.48
83-N32	Liver	205.90	11.47	0.37
83-N32	Ribs	40.50	12.21	2.59
83-N32	Lung	432.90	6.66	0.74
84-N33	Liver	187.50	2.96	-0.04
84-N33	Lung	200.35	0.74	1.85
84-N33	Ribs	27.80	3.33	6.29
84-N33	Vertebrae	35.80		
84-N33	Kidney	121.40	7.77	1.11
84-N34	Kidney	150.00	-0.37	0.19
84-N34	Liver	204.20	1.48	0.37
84-N34	Lung	255.30	3.70	2.22
84-N34	Ribs	36.20	16.28	1.85
84-N34	Vertebrae	83.80	7.77	1.85

Sample #	Tissue	Wet Weight (g)	Pu-239,240 mBq/kg wet	Pu-239,240 error mBq/kg wet
84-N35	Kidney	133.00	2.22	1.11
84-N35	Liver	420.00	19.98	0.74
84-N35	Lung	355.00	13.32	1.48
84-N35	Ribs	33.00	17.39	15.17
84-N35	Vertebrae	41.00	17.39	5.18
84-N36	Kidney	142.00	1.11	-0.74
84-N36	Liver	129.00	40.70	2.59
84-N36	Lung	182.00	11.10	0.37
84-N36	Ribs	33.00	14.80	-0.74
84-N36	Vertebrae	59.00	11.47	-2.22
84-N37	Kidney	116.40	0.04	-0.37
84-N37	Liver	238.10	7.40	1.11
84-N37	Lung	360.90	2.59	0.74
84-N37	Ribs	163.00	1.11	-4.81
84-N37	Vertebrae	15.00	24.42	17.02
84-N38	Kidney	100.20	-0.07	0.37
84-N38	Liver	402.40	20.72	2.22
84-N38	Lung	333.10	2.22	-0.07
84-N38	Ribs	67.90	14.06	3.70
84-N38	Vertebrae	26.60	5.55	1.85
84-N39	Kidney		2.22	-0.11
84-N39	Liver		18.50	6.29
84-N39	Lung		0.74	1.11
84-N39	Ribs		5.18	13.69
84-N39	Vertebrae		8.88	-0.37
84-N40	Kidney		0.74	0.74
84-N40	Liver		17.39	1.48
84-N40	Lung		5.55	0.74
84-N40	Ribs		52.54	0.37
84-N40	Vertebrae		5.18	5.92
84-N41	Kidney		0.37	1.85
84-N41	Liver		17.39	0.74
84-N41	Lung		3.33	0.74
84-N41	Ribs		12.95	-3.70
84-N42	Kidney		2.96	-2.22
84-N42	Liver		14.06	0.74
84-N42	Lung		20.35	2.22
84-N42	Ribs		21.09	-2.22
84-N42	Vertebrae		11.47	2.22
85-N43	Kidney		0.74	0.37
85-N43	Liver		7.40	1.85
85-N43	Lung		1.48	0.74
85-N43	Ribs		15.54	3.33

Sample #	Tissue	Wet Weight (g)	Pu-239,240 mBq/kg wet	Pu-239,240 error mBq/kg wet
85-N43	Vertebrae		10.36	2.22
85-N44	Kidney		0.37	1.48
85-N44	Liver		34.78	2.22
85-N44	Lung		2.96	-2.22
85-N44	Ribs		-2.22	8.51
85-N44	Vertebrae		2.22	-1.85
NF-27	Femur A			
NF-27	Femur B		14.43	0.74
NF-32	Femur A		3.33	-5.18
NF-32	Femur B			
NF-37	Femur A		10.73	7.03
NF-37	Femur B		5.18	-0.74
P04	Liver	1075.20	25.90	2.22
P04	Vertebrae	311.60	7.77	1.85
P04	Ribs	127.10	4.07	1.85
P04	Gonad	29.10	4.44	4.81
P04	Lung	526.00	2.96	1.11
P04	Kidney	178.90	1.11	1.11
P04	Sternum	18.90	15.91	8.14
P04	L.N.	19.40	1.48	12.95
P04	Spleen	222.30	1.48	2.22
P04	Thyroid	16.40	25.90	9.62
P05	Liver	242.20	44.03	3.70
P05	Lung	290.90		
P05	Kidney	93.10	0.74	1.11
P05	Vertebrae	223.10	8.51	2.22
P05	Ribs	126.50	13.69	2.96
P05	Sternum	27.40	-0.07	2.59
P06	Liver	278.73	73.63	3.70
P06	Lung	292.35	5.55	1.11
P06	Kidney	112.70	2.96	1.48
P06	Vertebrae	274.10	12.58	1.48
P06	Ribs	141.50	15.17	2.22
P06	Sternum	28.70	54.02	14.43
P07	Liver	272.80	42.55	4.44
P07	Lung	230.00	2.22	1.11
P07	Kidney	163.50	1.85	0.74
P07	L.N.	1.84	130.98	69.19
P07	Vertebrae	244.90	4.81	1.11
P07	Ribs	126.40	8.51	1.48
P07	Sternum	30.00	6.29	5.18
P08	Liver	285.13	4.07	1.11
P08	Lung	210.80	0.74	0.37

Sample #	Tissue	Wet Weight (g)	Pu-239,240 mBq/kg wet	Pu-239,240 error mBq/kg wet
P08	Kidney	82.80	1.85	1.11
P08	Spleen	135.00	1.85	0.74
P08	Thyroid	8.70	23.68	14.43
P08	L.N.	18.50	-3.33	1.85
P08	Ribs	106.00	9.25	2.22
P08	Sternum	16.00	19.61	13.32
P08	Vertebrae	132.00	8.14	1.85
P09	Lung	243.55	4.07	0.74
P09	Kidney	96.50	3.70	1.48
P09	Spleen	235.20		
P09	Gonad	22.80	2.22	4.07
P09	Ribs	115.00	7.03	2.22
P09	Sternum	20.00	9.62	7.03
P09	Vertebrae	220.00	8.14	1.48
P10	Liver	389.67	7.40	1.11
P10	Lung	229.50	1.48	0.37
P10	Kidney	129.00	-0.19	0.74
P10	Spleen	230.00	1.11	0.37
P10	Vertebrae	166.00	6.66	1.48
P10	Ribs	105.00	9.25	2.96
P10	Sternum	12.00	-18.50	7.03
P11	Liver	315.87	16.65	2.22
P11	Lung	222.10	7.03	1.48
P11	Kidney	161.00	0.37	0.74
P11	Spleen	158.20	0.74	1.48
P11	Thyroid	16.40	-6.29	3.33
P11	L.N.	3.79	-2.96	20.72
P11	Gonad	37.10	16.28	11.47
P11	Ribs	124.90	6.66	1.85
P11	Sternum	20.00	78.81	21.46
P11	Vertebrae	174.66	7.03	1.48
P12	Thyroid	17.40	0.74	7.40
P12	Liver	359.20	22.57	1.85
P12	Lung	589.60	1.85	0.74
P12	Kidney	132.90	-0.15	0.37
P12	Gonad	34.70	1.11	3.70
P12	Spleen	237.10	2.22	0.74
P12	Sternum	23.40	9.25	8.14
P12	L.N.	5.60	5.18	32.56
P12	Ribs	134.50	2.96	1.11
P12	Vertebrae	202.40	4.44	1.11
P13	Liver	390.55	8.51	0.74
P13	Lung	330.00	5.55	0.74

Sample #	Tissue	Wet Weight (g)	Pu-239,240 mBq/kg wet	Pu-239,240 error mBq/kg wet
P13	Kidney	156.70	2.96	1.48
P13	Spleen	65.50	-1.48	2.22
P13	Thyroid	21.50	-4.44	4.44
P13	Gonad	19.70	2.96	4.07
P13	L.N.	6.10		
P13	Ribs	136.40	15.54	1.85
P13	Sternum	24.10	116.18	15.91
P13	Vertebrae	190.90	23.68	2.59
P14	Lung	727.40	0.74	0.37
P14	Kidney	180.20	-1.85	1.48
P14	Liver	439.35	19.98	1.85
P14	Spleen	93.20	-0.74	1.48
P14	Thyroid	12.60		
P14	Gonad	20.00	-12.21	10.36
P14	L.N.	8.40	7.77	55.50
P14	Ribs	114.30	7.03	2.59
P14	Sternum	26.90	-1.48	5.18
P15	Spleen	110.80	11.10	2.59
P15	L.N.	29.70	-0.74	7.77
P15	Liver	361.87	15.17	1.48
P15	Lung	290.80	3.33	1.11
P15	Kidney	89.90	-0.74	4.81
P15	Thyroid	23.90	-13.32	15.91
P15	Gonad	19.10	31.82	29.23
P16	Liver	441.00	28.12	1.85
P16	Lung	322.70	4.81	1.11
P16	Kidney	175.70	-0.07	1.85
P16	Spleen	156.50	-2.96	2.22
P16	Thyroid	11.30	-7.03	7.03
P16	L.N.	12.60	17.39	11.10
P17	Kidney	115.30	-5.55	3.70
P17	Thyroid	15.00	-42.92	17.39
P17	L.N.	24.60	21.09	4.44
P17	Gonad	20.60	-15.91	9.25
S01	Kidney		0.00	0.74
S01	Liver		71.78	3.70
S01	Lung		8.51	1.85
S01	Ribs		-1.85	2.96
S01	Vertebrae		5.92	2.22
S02	Kidney		-0.74	1.11
S02	Liver		25.16	2.22
S02	Lung		5.92	0.74
S02	Ribs		1.48	9.25

Sample #	Tissue	Wet Weight (g)	Pu-239,240 mBq/kg wet	Pu-239,240 error mBq/kg wet
S02	Vertebrae			
S03	Kidney		1.11	1.48
S03	Kidney		1.11	1.48
S03	Liver		16.28	1.85
S04	Kidney		0.74	0.74
S04	Liver		15.17	1.11
S04	Lung		2.96	0.74
S04	Vertebrae		15.91	3.70
S05	Kidney		0.07	0.74
S05	Liver		17.39	1.48
S05	Lung		4.44	1.11
S05	Ribs		9.25	3.70
S05	Vertebrae		3.33	1.85
S06	Kidney		1.85	0.74
S06	Liver		44.40	2.96
S06	Lung		11.10	1.48
S06	Vertebrae		16.65	2.96
S07	Kidney		2.96	2.96
S07	Liver		14.06	1.11
S07	Vertebrae		18.87	2.59
S08	Kidney		0.37	0.37
S08	Liver		50.69	3.70
S08	Lung		0.37	0.37
S08	Ribs		17.02	9.25
S09	Kidney		20.72	9.25
S09	Liver		27.01	1.11
S09	Lung		15.17	2.22
S09	Ribs		8.51	5.18
S09	Vertebrae		17.02	2.22
SF01	Femur		7.77	1.85
SF02	Femur		5.92	2.22
SF03	Femur		4.44	1.48
SF04	Femur		11.10	1.85
SF05	Femur		11.47	1.85
SF06	Femur		10.36	3.33
SF07	Femur		5.18	1.85
SF08	Femur		1.11	0.74
SF09	Femur		5.18	1.85
SF10	Femur		12.95	3.33
SF11	Femur		12.21	4.44
SF12	Femur		11.84	5.18
SF13	Femur			
SF14	Femur		2.96	14.80

Sample #	Tissue	Wet Weight (g)	Pu-239,240 mBq/kg wet	Pu-239,240 error mBq/kg wet
SF15	Femur		5.18	1.48
SF16	Femur		5.92	2.96
SK01	Knee		14.06	4.44
SK02	Knee		2.96	2.22
SK03	Knee		-0.11	2.59
SK04	Knee		24.05	3.33
SK05	Knee		60.31	10.36
SK06	Knee		14.06	2.96
SK07	Knee		-0.74	7.03

Sample #	Tissue	Pu-238 mBq/kg wet	Pu-238 error mBq/kg wet
C09	Liver	1.85	0.74
C09	Lung	0.37	0.37
C09	Kidney	0.74	0.74
C09	Vertebrae	7.40	3.70
C09	Ribs	-1.85	6.29
C09	Sternum	-2.59	7.40
C10	Gonad	23.68	15.54
C10	Kidney	-3.33	1.85
C10	L.N.	12.58	113.59
C10	Liver	0.74	0.37
C10	Ribs	-5.55	4.81
C10	Spleen	1.11	1.11
C10	Thyroid	49.95	49.58
C10	Vertebrae	-2.22	3.33
C11	Liver	1.48	0.74
C11	Lung	1.11	0.74
C11	Kidney	0.37	0.74
C11	Vertebrae	1.11	2.22
C11	Spleen	1.85	1.85
C11	Thyroid	12.58	13.32
C12	Liver	1.48	1.48
C12	Lung	0.37	1.11
C12	Kidney	3.33	1.48
C12	L.N.	6.66	13.32
C12	Vertebrae	-4.07	2.96
C12	Ribs	-0.74	3.33
C12	Sternum	0.74	1.48
C13	Vertebrae	-4.44	4.81
C13	Ribs	-0.74	1.85
C13	Sternum	-0.74	0.74
C14	Liver	2.22	0.74
C14	Lung	2.59	1.11
C14	Kidney	0.37	0.37
C14	Spleen	0.74	0.74
C14	Vertebrae	0.37	2.59
C14	Gonad	1.48	5.18
C14	L.N.	29.97	36.26
C14	Thyroid	1.85	4.44
C15	Vertebrae	-2.59	1.85
C15	Ribs	7.40	7.40
C15	Sternum	-0.37	2.96
C15	L.N.	587.56	276.76
C15	Thyroid	5.92	14.06

Sample #	Tissue	Pu-238 mBq/kg wet	Pu-238 error mBq/kg wet
C15	Kidney	1.48	1.48
C15	Spleen	19.61	5.55
C15	Liver		
C15	Lung	0.37	0.37
C16	Liver	1.11	0.74
C16	Lung	0.74	0.74
C16	Kidney	1.11	0.74
C16	L.N.	-5.92	17.76
C16	Vertebrae	-1.11	2.22
C17	Liver	-0.15	0.37
C17	Lung	0.11	0.37
C17	Kidney	-1.48	0.74
C17	Spleen	0.74	0.74
C17	L.N.	71.41	62.90
C17	Gonad	1.11	6.66
C17	Thyroid	2.59	10.36
C17	Vertebrae	0.37	1.11
C18	Liver	0.74	0.74
C18	Lung	1.48	0.74
C18	Kidney	-0.74	1.11
C18	Spleen	-0.74	0.74
C18	Thyroid	-62.16	20.72
C19	Liver	2.59	0.74
C19	Lung	0.19	0.74
C19	Kidney	-0.19	1.48
C19	Spleen	-0.37	0.74
C19	Thyroid	4.81	8.88
C19	Gonad	6.66	7.03
C19	L.N.	-21.46	37.74
C19	Vertebrae		
C20	Liver	1.85	1.11
C20	Lung		
C20	Kidney	-0.37	0.74
C20	Spleen	2.96	1.85
C20	Thyroid	-0.74	6.66
C20	Gonad	-0.74	6.66
C20	Ribs	6.29	3.70
C20	Vertebrae		
C20	Sternum	-2.22	2.96
C21	Liver	0.37	0.37
C21	Lung	2.22	1.48
C21	Kidney	-1.11	2.22
C21	Spleen	0.74	0.74

Sample #	Tissue	Pu-238 mBq/kg wet	Pu-238 error mBq/kg wet
C21	Thyroid	11.47	19.61
C21	Vertebrae	-1.11	2.96
C22	Liver	-0.07	0.37
C22	Lung		
C22	Kidney		
C22	Spleen	1.11	1.11
C22	Thyroid	7.03	5.55
C22	Gonad	0.37	7.40
C22	Vertebrae	2.59	1.48
C22	L.N.	-122.10	44.40
C23	Liver	-0.37	0.37
C23	Lung	0.74	0.74
C23	Kidney	-5.55	1.11
C23	Spleen	-1.85	7.03
C23	Thyroid	6.66	16.28
C23	Gonad	30.71	22.57
C23	L.N.	-31.08	14.06
C23	Vertebrae	-1.11	1.11
82-N01	Liver	1.85	
82-N01	Vertebrae	2.59	
82-N02	Kidney	1.48	
82-N02	Liver	1.48	
82-N02	Ribs	6.29	
82-N02	Lung	0.74	
82-N03	Kidney		
82-N03	Liver	0.74	
82-N03	Vertebrae	9.62	
82-N04	Kidney	0.74	
82-N04	Liver	0.37	
82-N04	Ribs	5.92	
82-N04	Vertebrae	4.81	
82-N05	Kidney	1.48	
82-N05	Liver	0.74	
82-N05	Vertebrae	5.18	
82-N06	Kidney	0.74	
82-N06	Liver	0.11	
82-N06	Lung	0.74	
82-N06	Vertebrae	4.07	
82-N07	Kidney	0.74	
82-N07	Liver	1.11	
82-N07	Lung		
82-N07	Ribs	4.44	
82-N07	Vertebrae	5.18	

Sample #	Tissue	Pu-238 mBq/kg wet	Pu-238 error mBq/kg wet
82-N08	Kidney	1.48	
82-N08	Liver	0.74	
82-N08	Lung	0.37	
82-N08	Ribs	5.55	
82-N08	Vertebrae	1.11	
82-N09	Kidney	1.11	
82-N09	Liver	1.85	
82-N09	Lung	0.74	
82-N09	Ribs	4.44	
82-N09	Vertebrae	11.10	
82-N10	Kidney	0.37	
82-N10	Liver	0.74	
82-N10	Lung	0.37	
82-N11	Kidney	1.85	
82-N11	Liver	1.48	
82-N11	Lung	0.74	
82-N11	Ribs	4.44	
82-N11	Vertebrae	4.44	
82-N12	Kidney	0.37	
82-N12	Liver	0.74	
82-N12	Lung		
82-N12	Ribs	2.22	
82-N12	Vertebrae	2.59	
82-N13	Kidney	0.74	
82-N13	Liver	0.74	
82-N13	Lung		
82-N13	Ribs	4.07	
82-N13	Vertebrae	3.70	
82-N14	Kidney	0.74	
82-N14	Liver	0.37	
82-N14	Ribs	4.81	
82-N14	Vertebrae	2.22	
82-N15	Kidney	0.37	
82-N15	Liver	1.11	
82-N15	Lung	0.37	
82-N15	Ribs	6.66	
82-N15	Vertebrae	1.85	
82-N16	Kidney	0.74	
82-N16	Liver	0.37	
82-N16	Lung	0.37	
82-N16	Ribs	4.07	
82-N16	Vertebrae	2.22	
82-N17	Kidney	2.22	

Sample #	Tissue	Pu-238 mBq/kg wet	Pu-238 error mBq/kg wet
82-N17	Liver		
82-N17	Lung	1.48	
82-N17	Ribs	2.22	
82-N17	Vertebrae	2.96	
82-N18	Kidney	0.37	
82-N18	Lung	0.74	
82-N18	Ribs	5.92	
82-N18	Vertebrae	2.59	
83-N19	Kidney	1.48	
83-N19	Liver	1.11	
83-N19	Lung	0.37	
83-N19	Ribs	11.10	
83-N19	Vertebrae	1.85	
83-N20	Kidney	1.11	
83-N20	Liver	0.74	
83-N20	Lung		
83-N20	Ribs	4.07	
83-N20	Vertebrae	2.96	
83-N21	Kidney	1.48	
83-N21	Liver	0.74	
83-N21	Lung	3.70	
83-N21	Ribs	12.21	
83-N22	Kidney	0.74	
83-N22	Liver	0.37	
83-N22	Lung	1.11	
83-N22	Ribs	3.33	
83-N22	Vertebrae	2.22	
83-N23	Heart		
83-N23	Kidney	0.74	
83-N23	Liver	1.85	
83-N23	Lung	0.74	
83-N23	Ribs	6.66	
83-N23	Vertebrae	5.92	
83-N24	Kidney	1.11	
83-N24	Liver	4.81	
83-N24	Lung	0.37	
83-N24	Ribs	4.81	
83-N24	Vertebrae	10.73	
83-N25	Kidney	4.07	
83-N25	Liver	0.74	
83-N25	Lung	0.37	
83-N25	Ribs	0.74	
83-N25	Vertebrae	1.85	

Sample #	Tissue	Pu-238 mBq/kg wet	Pu-238 error mBq/kg wet
83-N26	Kidney	0.74	
83-N26	Liver	1.11	
83-N26	Lung	0.37	
83-N26	Ribs	12.58	
83-N26	Vertebrae	4.81	
83-N27	Kidney	1.11	
83-N27	Liver	0.74	
83-N27	Lung	0.37	
83-N27	Ribs	3.70	
83-N27	Vertebrae	2.96	
83-N28	Kidney	1.85	
83-N28	Liver	1.11	
83-N28	Lung	0.37	
83-N28	Ribs	3.70	
83-N29	Kidney	0.37	
83-N29	Liver	2.22	
83-N29	Lung	0.74	
83-N29	Ribs	6.66	
83-N29	Vertebrae	1.85	
83-N30	Kidney	1.11	
83-N30	Liver	1.11	
83-N30	Lung	0.37	
83-N30	Ribs	5.55	
83-N30	Vertebrae	9.25	
83-N31	Kidney	1.11	
83-N31	Liver	0.74	
83-N31	Ribs	5.55	
83-N31	Vertebrae	1.85	
83-N31	Lung	1.11	
83-N32	Kidney	1.11	
83-N32	Liver	0.74	
83-N32	Ribs	2.59	
83-N32	Lung	0.37	
84-N33	Liver	0.74	
84-N33	Lung	1.48	
84-N33	Ribs	7.03	
84-N33	Vertebrae		
84-N33	Kidney	6.29	
84-N34	Kidney	0.74	
84-N34	Liver	0.74	
84-N34	Lung	0.74	
84-N34	Ribs	3.33	
84-N34	Vertebrae	4.44	

Sample #	Tissue	Pu-238 mBq/kg wet	Pu-238 error mBq/kg wet
84-N35	Kidney	1.11	
84-N35	Liver	0.37	
84-N35	Lung	1.11	
84-N35	Ribs	6.29	
84-N35	Vertebrae	4.81	
84-N36	Kidney	0.37	
84-N36	Liver	1.11	
84-N36	Lung	1.11	
84-N36	Ribs	3.70	
84-N36	Vertebrae	2.59	
84-N37	Kidney	0.74	
84-N37	Liver	0.74	
84-N37	Lung	0.74	
84-N37	Ribs	5.92	
84-N37	Vertebrae	12.58	
84-N38	Kidney	1.11	
84-N38	Liver	0.74	
84-N38	Lung	0.37	
84-N38	Ribs	2.96	
84-N38	Vertebrae	4.81	
84-N39	Kidney	1.11	
84-N39	Liver	2.59	
84-N39	Lung	0.74	
84-N39	Ribs	6.66	
84-N39	Vertebrae	2.22	
84-N40	Kidney	0.74	
84-N40	Liver	0.74	
84-N40	Lung	0.74	
84-N40	Ribs	6.66	
84-N40	Vertebrae	4.44	
84-N41	Kidney	1.48	
84-N41	Liver	0.37	
84-N41	Lung	0.37	
84-N41	Ribs	9.62	
84-N42	Kidney	2.96	
84-N42	Liver	0.74	
84-N42	Lung	1.11	
84-N42	Ribs	1.11	
84-N42	Vertebrae	3.70	
85-N43	Kidney	1.11	
85-N43	Liver	1.48	
85-N43	Lung	1.11	
85-N43	Ribs	5.18	

Sample #	Tissue	Pu-238 mBq/kg wet	Pu-238 error mBq/kg wet
85-N43	Vertebrae	3.70	
85-N44	Kidney	1.11	
85-N44	Liver	0.74	
85-N44	Lung	1.11	
85-N44	Ribs	12.95	
85-N44	Vertebrae	1.11	
NF-27	Femur A		
NF-27	Femur B	4.44	
NF-32	Femur A	3.33	
NF-32	Femur B		
NF-37	Femur A	2.96	
NF-37	Femur B	2.59	
P04	Liver	2.22	0.74
P04	Vertebrae	1.11	0.74
P04	Ribs	0.37	1.85
P04	Gonad	2.59	4.44
P04	Lung	1.48	1.11
P04	Kidney	1.11	2.22
P04	Sternum	19.98	8.88
P04	L.N.	-10.36	18.13
P04	Spleen	1.11	0.74
P04	Thyroid	18.50	8.14
P05	Liver	3.70	1.11
P05	Lung		
P05	Kidney	1.85	1.11
P05	Vertebrae	2.96	1.11
P05	Ribs	-1.11	1.48
P05	Sternum	1.48	5.92
P06	Liver	1.85	0.74
P06	Lung	1.11	0.37
P06	Kidney	5.18	1.85
P06	Vertebrae	2.59	1.11
P06	Ribs	0.37	1.48
P06	Sternum	19.24	8.51
P07	Liver	-0.74	1.11
P07	Lung	-0.07	0.37
P07	Kidney	0.74	0.74
P07	L.N.	120.25	81.77
P07	Vertebrae	1.11	0.74
P07	Ribs	0.74	2.22
P07	Sternum	-1.85	5.18
P08	Liver	0.74	0.37
P08	Lung	0.37	0.74

Sample #	Tissue	Pu-238 mBq/kg wet	Pu-238 error mBq/kg wet
P08	Kidney	0.74	1.11
P08	Spleen	0.37	0.74
P08	Thyroid	-17.02	14.43
P08	L.N.	-9.25	4.81
P08	Ribs	-0.37	0.74
P08	Sternum	-3.33	14.06
P08	Vertebrae	0.15	1.11
P09	Lung	1.85	0.74
P09	Kidney	-0.01	1.85
P09	Spleen		
P09	Gonad	-0.37	6.29
P09	Ribs	-2.59	1.48
P09	Sternum	-5.55	6.66
P09	Vertebrae	1.11	0.74
P10	Liver	1.11	0.37
P10	Lung	-0.74	0.74
P10	Kidney	0.74	0.74
P10	Spleen	-0.74	0.37
P10	Vertebrae	1.48	1.11
P10	Ribs	7.03	2.59
P10	Sternum	7.03	14.43
P11	Liver	1.48	1.11
P11	Lung	-0.11	0.74
P11	Kidney	0.37	0.74
P11	Spleen	1.48	1.11
P11	Thyroid	-3.33	5.55
P11	L.N.	7.77	23.31
P11	Gonad	25.90	12.95
P11	Ribs	1.11	1.11
P11	Sternum	14.06	9.99
P11	Vertebrae	0.37	0.74
P12	Thyroid	0.07	8.51
P12	Liver	1.85	0.74
P12	Lung	-0.01	0.37
P12	Kidney	-0.74	0.37
P12	Gonad	-0.74	3.70
P12	Spleen	1.11	0.74
P12	Sternum	4.07	10.36
P12	L.N.	-73.63	49.58
P12	Ribs	-0.74	1.11
P12	Vertebrae	-0.04	0.74
P13	Liver	2.22	0.37
P13	Lung	-0.37	0.37

Sample #	Tissue	Pu-238 mBq/kg wet	Pu-238 error mBq/kg wet
P13	Kidney	0.74	1.48
P13	Spleen	2.22	2.59
P13	Thyroid	-1.11	5.92
P13	Gonad	-7.77	5.18
P13	L.N.		
P13	Ribs	-0.74	1.11
P13	Sternum	-3.70	5.55
P13	Vertebrae	0.37	0.74
P14	Lung	-1.11	0.37
P14	Kidney	0.37	0.74
P14	Liver	0.74	0.37
P14	Spleen	0.37	1.11
P14	Thyroid	-24.05	19.98
P14	Gonad	-4.07	6.66
P14	L.N.	-9.25	24.79
P14	Ribs	-2.59	1.48
P14	Sternum	12.21	7.03
P15	Spleen	0.74	1.48
P15	L.N.	2.22	5.18
P15	Liver	0.74	0.37
P15	Lung	0.11	0.74
P15	Kidney	-1.48	2.59
P15	Thyroid	5.55	7.40
P15	Gonad	0.37	14.80
P16	Liver	1.85	0.74
P16	Lung	1.85	0.74
P16	Kidney	-0.37	0.74
P16	Spleen	-1.11	1.48
P16	Thyroid	-28.49	14.06
P16	L.N.	1.85	11.47
P17	Kidney	-0.11	2.22
P17	Thyroid	37.00	29.97
P17	L.N.	6.29	4.81
P17	Gonad	4.07	5.92
S01	Kidney	-0.74	0.74
S01	Liver	1.85	1.48
S01	Lung	-2.96	2.59
S01	Ribs	2.59	5.18
S01	Vertebrae	2.22	1.48
S02	Kidney	0.07	1.85
S02	Liver	-0.19	0.37
S02	Lung	0.37	0.37
S02	Ribs	-9.25	10.36

Sample #	Tissue	Pu-238 mBq/kg wet	Pu-238 error mBq/kg wet
S02	Vertebrae		
S03	Kidney	1.85	1.11
S03	Kidney	-0.37	1.85
S03	Liver	-0.37	1.85
S04	Kidney	-1.11	0.74
S04	Liver	0.74	0.37
S04	Lung	-0.74	1.48
S04	Vertebrae	1.11	2.22
S05	Kidney	-1.11	1.11
S05	Liver	0.37	0.37
S05	Lung	0.37	0.74
S05	Ribs	-3.70	2.59
S05	Vertebrae	1.11	1.85
S06	Kidney	1.85	1.48
S06	Liver	2.22	0.74
S06	Lung	2.22	0.74
S06	Vertebrae	-1.11	0.74
S07	Kidney	-4.81	3.33
S07	Liver	0.74	0.37
S07	Vertebrae	-0.74	1.48
S08	Kidney	0.19	0.37
S08	Liver	3.70	1.11
S08	Lung	0.74	0.37
S08	Ribs	8.51	8.88
S09	Kidney	18.13	11.47
S09	Liver	1.11	0.37
S09	Lung	-0.37	0.74
S09	Ribs	-8.88	3.70
S09	Vertebrae	0.37	0.74
SF01	Femur	0.04	1.48
SF02	Femur	-1.85	1.11
SF03	Femur	2.59	1.48
SF04	Femur	3.70	1.48
SF05	Femur	2.96	1.85
SF06	Femur	4.81	3.33
SF07	Femur	1.85	1.48
SF08	Femur	2.22	1.48
SF09	Femur	2.59	1.48
SF10	Femur	-1.48	1.48
SF11	Femur	-4.81	3.33
SF12	Femur	2.59	2.96
SF13	Femur		
SF14	Femur	-4.81	15.17

Sample #	Tissue	Pu-238 mBq/kg wet	Pu-238 error mBq/kg wet
SF15	Femur	2.59	1.48
SF16	Femur	2.22	2.96
SK01	Knee	2.59	3.33
SK02	Knee	-2.59	2.96
SK03	Knee	-0.37	3.33
SK04	Knee	-0.04	1.85
SK05	Knee	4.44	3.70
SK06	Knee	0.37	1.48
SK07	Knee	0.74	3.33

Sample #	Tissue	U-238 mBq/kg wet	U-238 error mBq/kg wet	U-235 mBq/kg wet
C09	Liver	28.12	2.59	1.11
C09	Lung	73.26	4.07	2.22
C09	Kidney	125.80	5.92	4.81
C09	Vertebrae	172.42	15.91	7.40
C09	Ribs	103.97	13.32	2.96
C09	Sternum	146.52	22.57	11.47
C10	Gonad	32.19	13.69	-9.62
C10	Kidney	48.10	4.44	4.07
C10	L.N.	731.86	260.85	-13.69
C10	Liver	2.59	0.74	-0.37
C10	Ribs	71.41	11.84	-0.19
C10	Spleen	5.18	1.48	0.07
C10	Thyroid	69.93	32.19	
C10	Vertebrae	42.18	5.92	1.48
C11	Liver	3.70	0.74	0.07
C11	Lung	84.36	3.70	4.07
C11	Kidney	9.99	1.85	0.74
C11	Vertebrae	17.76	4.81	1.85
C11	Spleen	3.70	1.48	1.48
C11	Thyroid	27.75	21.46	9.25
C12	Liver	2.96	1.11	0.74
C12	Lung	65.86	3.70	1.48
C12	Kidney	17.39	2.59	2.22
C12	L.N.	46.62	24.79	34.04
C12	Vertebrae	21.83	9.62	-4.81
C12	Ribs	13.69	3.70	0.74
C12	Sternum	7.40	3.33	0.74
C13	Vertebrae	55.87	12.58	-0.19
C13	Ribs	27.38	5.18	-0.04
C13	Sternum	43.66	5.92	4.44
C14	Liver	2.96	0.74	1.11
C14	Lung	29.97	2.22	1.48
C14	Kidney	21.46	2.59	1.11
C14	Spleen	3.70	0.74	0.37
C14	Vertebrae	20.72	4.07	-0.37
C14	Gonad	2.96	6.66	0.74
C14	L.N.	90.65	55.50	3.33
C14	Thyroid	11.10	7.77	-12.21
C15	Vertebrae	13.69	3.70	1.11
C15	Ribs	20.72	11.10	0.00
C15	Sternum	32.56	7.40	-0.11
C15	L.N.	715.95	481.00	49.95
C15	Thyroid	51.06	37.00	37.00

Sample #	Tissue	U-238 mBq/kg wet	U-238 error mBq/kg wet	U-235 mBq/kg wet
C15	Kidney	18.13	2.22	0.74
C15	Spleen	68.45	9.99	-2.59
C15	Liver	14.06	1.48	0.37
C15	Lung	6.29	0.74	1.48
C16	Liver	3.70	1.11	0.37
C16	Lung	11.47	2.22	1.11
C16	Kidney	7.03	1.48	-0.37
C16	L.N.	150.96	55.50	4.07
C16	Vertebrae	25.16	4.81	0.74
C17	Liver	4.07	0.74	0.04
C17	Lung	1.11	0.37	-0.37
C17	Kidney	12.21	1.85	0.15
C17	Spleen	3.33	1.11	0.37
C17	L.N.	101.75	76.96	35.89
C17	Gonad	23.31	12.58	4.81
C17	Thyroid	31.08	12.21	-2.96
C17	Vertebrae	11.10	1.85	-0.15
C18	Liver	0.74	0.37	-0.11
C18	Lung	7.77	1.11	1.48
C18	Kidney	2.59	1.11	3.33
C18	Spleen	3.33	0.74	-0.37
C18	Thyroid	-8.14	1.48	-18.87
C19	Liver	0.74	0.37	-0.07
C19	Lung	7.77	1.48	0.37
C19	Kidney	1.48	1.48	-0.15
C19	Spleen	3.33	1.85	2.59
C19	Thyroid	-0.37	13.69	-7.40
C19	Gonad	0.74	4.81	-0.19
C19	L.N.	98.42	48.84	-5.18
C19	Vertebrae	7.40	2.22	1.85
C20	Liver	31.08	2.96	0.37
C20	Lung	119.14	5.18	3.70
C20	Kidney	24.05	3.33	-0.11
C20	Spleen	11.10	2.59	0.74
C20	Thyroid	42.92	13.32	0.37
C20	Gonad			
C20	Ribs	39.22	8.88	-1.85
C20	Vertebrae	32.56	4.44	3.70
C20	Sternum	14.06	3.33	2.22
C21	Liver	1.85	0.37	0.37
C21	Lung	2.59	0.74	0.37
C21	Kidney	1.48	2.96	-0.19
C21	Spleen	1.48	1.48	2.22

Sample #	Tissue	U-238 mBq/kg wet	U-238 error mBq/kg wet	U-235 mBq/kg wet
C21	Thyroid	17.76	42.55	42.55
C21	Vertebrae	53.28	13.32	6.29
C22	Liver	2.96	1.11	2.59
C22	Lung	19.24	1.48	1.48
C22	Kidney	14.43	2.96	1.11
C22	Spleen	0.37	1.11	0.74
C22	Thyroid	10.73	12.58	-2.96
C22	Gonad	7.03	4.81	0.37
C22	Vertebrae	17.39	7.77	0.74
C22	L.N.	-35.52	59.20	111.00
C23	Liver	4.07	1.85	-0.37
C23	Lung	2.22	1.11	-1.11
C23	Kidney	11.10	2.96	1.48
C23	Spleen	-0.37	1.48	-0.37
C23	Thyroid	6.29	8.51	11.84
C23	Gonad	-5.92	18.87	7.40
C23	L.N.	27.38	48.10	19.98
C23	Vertebrae	1.85	1.48	1.48
82-N01	Liver	1.11	-0.37	0.37
82-N01	Vertebrae	7.40	2.96	4.81
82-N02	Kidney	2.22	1.85	1.11
82-N02	Liver	0.15	0.37	0.07
82-N02	Ribs	21.46	-4.81	4.44
82-N02	Lung	0.74	0.74	0.37
82-N03	Kidney	2.22	0.37	1.48
82-N03	Liver	0.74	-0.37	0.37
82-N03	Vertebrae	4.81	-1.85	2.22
82-N04	Kidney	3.70	-1.48	1.11
82-N04	Liver	0.74	-0.37	0.37
82-N04	Ribs	27.38	1.11	13.69
82-N04	Vertebrae	8.51	-1.48	5.55
82-N05	Kidney	2.96	-2.59	2.59
82-N05	Liver	0.74	-0.37	0.37
82-N05	Vertebrae	5.18	-2.22	2.96
82-N06	Kidney	1.48	0.11	0.74
82-N06	Liver	0.37	0.37	0.37
82-N06	Lung	1.48	0.01	0.37
82-N06	Vertebrae			
82-N07	Kidney	2.22	0.04	0.37
82-N07	Liver	1.48	0.37	0.37
82-N07	Lung	1.11	0.37	0.37
82-N07	Ribs	12.58	3.33	5.18
82-N07	Vertebrae	6.29		1.48

Sample #	Tissue	U-238 mBq/kg wet	U-238 error mBq/kg wet	U-235 mBq/kg wet
82-N08	Kidney	1.85	-0.04	0.74
82-N08	Liver	0.74	0.04	0.37
82-N08	Lung	1.48	0.74	0.37
82-N08	Ribs	8.88	3.33	3.33
82-N08	Vertebrae	3.70	2.22	3.33
82-N09	Kidney	2.59	0.04	0.74
82-N09	Liver	0.74	0.37	0.37
82-N09	Lung	1.11	0.37	0.37
82-N09	Ribs	26.64	-14.43	9.99
82-N09	Vertebrae	34.41	20.72	20.35
82-N10	Kidney	1.85	0.15	0.37
82-N10	Liver	0.37	0.37	0.19
82-N10	Lung	1.48	0.74	0.37
82-N11	Kidney	1.85	0.07	0.74
82-N11	Liver	1.85	-0.04	0.74
82-N11	Lung	1.85	1.11	0.37
82-N11	Ribs	9.25	1.85	2.96
82-N11	Vertebrae	5.18	-0.15	1.48
82-N12	Kidney	0.74	0.15	0.37
82-N12	Liver	1.48	-0.19	0.37
82-N12	Lung	0.74	0.07	0.11
82-N12	Ribs	4.07	1.85	2.96
82-N12	Vertebrae	4.07	0.74	1.11
82-N13	Kidney	3.70	2.96	0.74
82-N13	Liver	0.37	0.37	0.37
82-N13	Lung	0.74	0.11	0.15
82-N13	Ribs	9.25	3.70	2.59
82-N13	Vertebrae	3.70	0.37	1.11
82-N14	Kidney	1.48	0.74	0.37
82-N14	Liver	0.74	0.15	0.37
82-N14	Ribs	8.14	4.07	2.96
82-N14	Vertebrae	5.55	1.85	3.33
82-N15	Kidney	1.85	0.37	0.37
82-N15	Liver	1.85	-0.37	0.74
82-N15	Lung	1.48	1.48	0.37
82-N15	Ribs	8.14	-1.11	1.85
82-N15	Vertebrae	6.29	-0.74	1.85
82-N16	Kidney	2.22	0.37	0.74
82-N16	Liver	0.74	0.37	0.37
82-N16	Lung	2.59	0.74	0.74
82-N16	Ribs	7.77	-1.48	2.96
82-N16	Vertebrae	2.22	0.74	0.74
82-N17	Kidney	3.70	-0.37	0.37

Sample #	Tissue	U-238 mBq/kg wet	U-238 error mBq/kg wet	U-235 mBq/kg wet
82-N17	Liver	1.85	0.37	0.37
82-N17	Lung	1.11	0.01	0.37
82-N17	Ribs	6.66	-0.74	2.59
82-N17	Vertebrae	4.07	0.15	1.48
82-N18	Kidney	1.48	0.37	0.37
82-N18	Lung	2.22	-0.15	0.37
82-N18	Ribs	13.32	0.11	3.70
82-N18	Vertebrae	7.03	-2.59	1.48
83-N19	Kidney	4.44	2.22	1.11
83-N19	Liver	0.37	0.11	0.15
83-N19	Lung	1.48	0.74	0.37
83-N19	Ribs	7.40	-0.37	2.59
83-N19	Vertebrae	4.07	-0.74	1.11
83-N20	Kidney	2.59	0.74	0.74
83-N20	Liver	1.48	0.74	0.74
83-N20	Lung	1.48	0.37	0.37
83-N20	Ribs	6.66	-1.48	1.85
83-N20	Vertebrae	4.07	-0.07	1.11
83-N21	Kidney	2.59	-0.37	0.74
83-N21	Liver	0.37	0.04	0.15
83-N21	Lung	1.85	0.37	0.74
83-N21	Ribs	22.94	-8.88	16.28
83-N22	Kidney	2.22	0.74	0.74
83-N22	Liver	0.74	0.37	0.19
83-N22	Lung	2.96	0.74	0.74
83-N22	Ribs	14.06	8.51	6.29
83-N22	Vertebrae	5.55	1.48	1.85
83-N23	Heart			
83-N23	Kidney	1.11	-0.37	0.37
83-N23	Liver	1.48	0.37	0.74
83-N23	Lung	1.85	1.48	0.37
83-N23	Ribs	12.58	11.84	13.69
83-N23	Vertebrae	5.18	0.37	2.59
83-N24	Kidney	1.85	1.11	1.11
83-N24	Liver	2.59	0.37	1.48
83-N24	Lung	2.22	14.80	0.74
83-N24	Ribs	6.66	0.11	2.59
83-N24	Vertebrae	2.96	2.22	1.85
83-N25	Kidney	2.96	0.74	1.11
83-N25	Liver	1.48	1.48	0.74
83-N25	Lung	0.74	0.04	0.37
83-N25	Ribs	3.70	0.37	1.85
83-N25	Vertebrae	3.70	-1.11	1.11

Sample #	Tissue	U-238 mBq/kg wet	U-238 error mBq/kg wet	U-235 mBq/kg wet
83-N26	Kidney	1.48	-0.04	0.37
83-N26	Liver	0.74	0.37	0.37
83-N26	Lung	1.11	0.37	0.37
83-N26	Ribs	9.99	5.18	3.70
83-N26	Vertebrae	4.81	-0.37	4.07
83-N27	Kidney	1.48	-0.37	0.37
83-N27	Liver	1.48	0.74	0.37
83-N27	Lung	1.48	0.37	0.37
83-N27	Ribs	4.81	-0.04	1.85
83-N27	Vertebrae	4.07	-3.33	2.22
83-N28	Kidney	1.85	1.85	0.74
83-N28	Liver	1.11	0.37	0.74
83-N28	Lung	1.11	0.74	0.37
83-N28	Ribs	8.14	-3.33	4.07
83-N29	Kidney	1.48	0.74	0.37
83-N29	Liver	0.74	0.37	0.37
83-N29	Lung	1.48	0.37	0.37
83-N29	Ribs	4.07	0.37	1.11
83-N29	Vertebrae	4.07	-0.04	1.11
83-N30	Kidney	0.37	1.11	1.11
83-N30	Liver	1.48	0.04	0.37
83-N30	Lung	1.85	0.07	0.37
83-N30	Ribs	4.81	-0.74	0.74
83-N30	Vertebrae	16.28	-1.85	7.77
83-N31	Kidney	1.48	-0.04	0.37
83-N31	Liver	1.11	0.37	0.37
83-N31	Ribs	8.51	6.29	4.07
83-N31	Vertebrae	3.33	1.85	1.48
83-N31	Lung	1.85	0.37	0.37
83-N32	Kidney	3.33	1.11	1.11
83-N32	Liver	1.85	0.37	0.37
83-N32	Ribs	6.66	-0.37	1.85
83-N32	Lung	0.74	0.37	0.37
84-N33	Liver	1.11	0.74	0.37
84-N33	Lung	1.85	-1.48	1.11
84-N33	Ribs	7.77	1.85	3.70
84-N33	Vertebrae	11.84	9.99	8.51
84-N33	Kidney	5.55	5.92	4.44
84-N34	Kidney	3.70	1.85	1.11
84-N34	Liver	6.29	7.40	1.85
84-N34	Lung	2.22	1.85	0.74
84-N34	Ribs	10.73	5.18	4.81
84-N34	Vertebrae	7.40	4.44	2.96

Sample #	Tissue	U-238 mBq/kg wet	U-238 error mBq/kg wet	U-235 mBq/kg wet
84-N35	Kidney	2.22	0.74	1.11
84-N35	Liver	1.48	1.11	0.37
84-N35	Lung	1.85	0.74	0.37
84-N35	Ribs	11.84	15.91	7.03
84-N35	Vertebrae	11.47	2.22	5.18
84-N36	Kidney	2.96	0.37	0.74
84-N36	Liver	1.85	0.74	0.74
84-N36	Lung	2.96	0.74	0.74
84-N36	Ribs	36.26	28.12	7.03
84-N36	Vertebrae	5.92	0.37	2.59
84-N37	Kidney	1.48	1.11	0.74
84-N37	Liver	1.11	0.74	0.74
84-N37	Lung	1.48	0.37	0.37
84-N37	Ribs	14.06	2.22	6.66
84-N37	Vertebrae	21.83	8.51	9.99
84-N38	Kidney	2.22	1.11	1.11
84-N38	Liver	1.11	0.74	0.37
84-N38	Lung	1.11	0.37	0.37
84-N38	Ribs	3.70	0.74	1.48
84-N38	Vertebrae	11.47	6.29	5.18
84-N39	Kidney	1.85	0.74	0.74
84-N39	Liver	1.85	2.59	1.85
84-N39	Lung	1.85	1.85	0.74
84-N39	Ribs	6.66	2.59	4.07
84-N39	Vertebrae	2.59	-1.11	2.22
84-N40	Kidney	1.11	0.37	0.74
84-N40	Liver	0.74	0.74	0.74
84-N40	Lung	1.85	0.74	0.74
84-N40	Ribs	5.55	0.37	2.96
84-N40	Vertebrae	4.07	1.85	2.96
84-N41	Kidney	1.85	1.11	1.11
84-N41	Liver	0.74	0.74	0.37
84-N41	Lung	1.11	0.74	0.37
84-N41	Ribs	7.77	12.21	9.62
84-N42	Kidney	2.22	1.11	0.74
84-N42	Liver	0.74	-0.37	0.37
84-N42	Lung	2.96	1.85	0.74
84-N42	Ribs	5.18	7.77	4.44
84-N42	Vertebrae	2.22	2.96	1.85
85-N43	Kidney	4.44	3.33	1.11
85-N43	Liver	2.96	-5.55	5.55
85-N43	Lung	1.11	0.04	1.11
85-N43	Ribs	6.66	7.03	3.70

Sample #	Tissue	U-238 mBq/kg wet	U-238 error mBq/kg wet	U-235 mBq/kg wet
85-N43	Vertebrae	4.44	1.11	1.11
85-N44	Kidney	0.74	0.74	0.37
85-N44	Liver	0.74	0.74	0.37
85-N44	Lung	1.48	0.15	0.37
85-N44	Ribs	5.55	5.18	3.70
85-N44	Vertebrae	1.85	0.37	1.11
NF-27	Femur A			
NF-27	Femur B	7.77	7.40	5.55
NF-32	Femur A			
NF-32	Femur B	9.99	5.55	3.33
NF-37	Femur A	4.07	3.70	1.85
NF-37	Femur B	4.07	-4.07	2.22
P04	Liver	0.74	0.74	-0.15
P04	Vertebrae	11.10	2.22	1.11
P04	Ribs	9.62	3.33	1.48
P04	Gonad	1.11	6.29	2.22
P04	Lung	12.58	1.85	1.48
P04	Kidney	4.81	1.48	0.37
P04	Sternum	50.32	18.87	-11.10
P04	L.N.	18.87	14.06	7.40
P04	Spleen	0.04	0.74	-0.01
P04	Thyroid	24.42	32.56	1.11
P05	Liver	3.33	1.11	1.11
P05	Lung	66.23	4.07	3.70
P05	Kidney	7.77	2.22	-0.37
P05	Vertebrae	3.33	1.48	0.15
P05	Ribs	5.18	2.96	0.74
P05	Sternum	9.25	9.99	-2.59
P06	Liver	1.85	0.74	0.74
P06	Lung	38.48	2.59	2.22
P06	Kidney	4.44	1.85	-1.11
P06	Vertebrae	9.62	1.85	1.11
P06	Ribs	9.25	3.33	1.48
P06	Sternum	46.62	15.91	-0.15
P07	Liver	1.48	0.74	0.74
P07	Lung	9.99	1.85	0.07
P07	Kidney	5.18	1.48	0.07
P07	L.N.	120.99	107.30	111.37
P07	Vertebrae	9.25	2.59	0.74
P07	Ribs	13.32	5.55	0.15
P07	Sternum	48.10	11.84	-0.01
P08	Liver	2.96	0.74	0.15
P08	Lung	9.99	1.11	-0.37

Sample #	Tissue	U-238 mBq/kg wet	U-238 error mBq/kg wet	U-235 mBq/kg wet
P08	Kidney	3.70	1.48	1.85
P08	Spleen	7.77	1.48	0.04
P08	Thyroid	49.95	22.20	17.39
P08	L.N.	23.31	8.51	9.99
P08	Ribs	12.58	3.33	0.74
P08	Sternum	15.91	13.69	1.85
P08	Vertebrae	4.81	1.48	0.74
P09	Lung	14.43	1.48	-0.07
P09	Kidney	0.74	2.59	4.81
P09	Spleen	5.18	1.11	0.19
P09	Gonad	15.17	8.88	-2.59
P09	Ribs	6.66	1.48	-0.15
P09	Sternum	39.59	15.91	2.59
P09	Vertebrae	24.79	2.22	1.11
P10	Liver	1.11	0.37	0.37
P10	Lung	8.14	1.48	0.15
P10	Kidney	6.29	2.22	0.74
P10	Spleen	1.11	0.74	-0.11
P10	Vertebrae	41.81	4.44	1.48
P10	Ribs	12.95	3.70	2.59
P10	Sternum	164.65	57.35	28.49
P11	Liver	8.51	1.48	0.74
P11	Lung	5.55	0.74	-0.37
P11	Kidney	1.11	0.74	0.37
P11	Spleen	-0.11	0.37	0.74
P11	Thyroid	-11.47	2.22	-6.66
P11	L.N.	-18.87	4.81	-36.26
P11	Gonad	-2.22	1.85	2.59
P11	Ribs	22.94	2.59	0.07
P11	Sternum	54.39	12.58	0.74
P11	Vertebrae	32.56	3.70	-0.07
P12	Thyroid	-16.28		4.81
P12	Liver	1.11	0.37	0.37
P12	Lung	25.16	1.85	1.48
P12	Kidney	9.25	2.22	1.48
P12	Gonad	-4.44	5.18	3.70
P12	Spleen	1.85	0.74	0.07
P12	Sternum	-1.48	5.18	-0.37
P12	L.N.	434.01	66.23	49.21
P12	Ribs	7.03	2.59	0.74
P12	Vertebrae	7.40	1.48	0.74
P13	Liver	2.22	0.74	-0.01
P13	Lung	7.40	1.11	1.11

Sample #	Tissue	U-238 mBq/kg wet	U-238 error mBq/kg wet	U-235 mBq/kg wet
P13	Kidney	9.99	2.22	1.48
P13	Spleen	7.40	3.33	1.48
P13	Thyroid	-5.92	10.73	-1.11
P13	Gonad	-1.85	7.77	1.48
P13	L.N.	108.78	38.11	3.70
P13	Ribs	1.11	1.48	0.74
P13	Sternum	37.37	22.57	6.66
P13	Vertebrae	16.65	2.22	1.48
P14	Lung	2.22	0.74	0.04
P14	Kidney			
P14	Liver	0.74	0.74	0.37
P14	Spleen	-1.11	1.11	1.11
P14	Thyroid	4.81	16.28	-3.70
P14	Gonad	1.85	7.03	
P14	L.N.	-26.64	15.54	6.66
P14	Ribs	4.81	2.22	1.85
P14	Sternum	14.80	8.51	-3.33
P15	Spleen	2.96	1.85	-0.74
P15	L.N.	81.77	31.45	12.21
P15	Liver	0.74	0.74	0.11
P15	Lung	11.10	1.48	-0.37
P15	Kidney	1.11	3.70	-1.48
P15	Thyroid	7.40	9.25	-1.11
P15	Gonad	-12.95	8.88	3.33
P16	Liver	5.18	1.11	0.37
P16	Lung	5.92	2.22	0.37
P16	Kidney	4.81	1.85	-0.37
P16	Spleen	1.48	1.48	-0.74
P16	Thyroid	-22.57	13.69	9.62
P16	L.N.	35.15	21.46	0.04
P17	Kidney	1.48	1.48	-0.37
P17	Thyroid	14.06	39.96	-4.07
P17	L.N.	69.19	10.36	0.74
P17	Gonad	7.77	8.14	-3.33
S01	Kidney	14.80	2.22	0.37
S01	Liver	7.40	1.11	0.19
S01	Lung	57.72	5.92	4.44
S01	Ribs	24.79	5.92	1.85
S01	Vertebrae			
S02	Kidney	13.32	2.96	1.11
S02	Liver	2.59	0.37	0.07
S02	Lung	11.47	1.11	0.37
S02	Ribs	61.79	19.98	5.92

Sample #	Tissue	U-238 mBq/kg wet	U-238 error mBq/kg wet	U-235 mBq/kg wet
S02	Vertebrae	8.88	1.85	-0.19
S03	Kidney	35.52	4.44	1.85
S03	Kidney	37.37	2.96	1.48
S03	Liver	30.34	2.59	0.74
S04	Kidney	34.04	3.33	1.48
S04	Liver	16.28	1.11	0.11
S04	Lung	30.34	2.22	1.11
S04	Vertebrae	14.43	2.59	0.74
S05	Kidney	9.62	2.22	0.74
S05	Liver	5.55	1.11	1.48
S05	Lung	13.32	1.48	0.74
S05	Ribs	7.77	3.33	-1.48
S05	Vertebrae	10.73	2.96	2.22
S06	Kidney	5.18	1.85	0.74
S06	Liver	24.42	1.85	1.11
S06	Lung	29.60	2.22	2.59
S06	Vertebrae	4.81	3.70	0.37
S07	Kidney	46.62	9.25	3.33
S07	Liver	10.73	1.11	0.37
S07	Vertebrae	75.11	6.66	2.59
S08	Kidney	8.88	1.11	0.74
S08	Liver	4.07	0.74	-0.37
S08	Lung	17.76	1.85	0.37
S08	Ribs	18.50	7.03	-0.37
S09	Kidney	58.09	14.06	-0.37
S09	Liver	3.70	0.74	0.01
S09	Lung	32.19	1.85	0.74
S09	Ribs	42.55	17.39	24.79
S09	Vertebrae	12.58	2.22	0.37
SF01	Femur	3.70	5.18	6.29
SF02	Femur	16.28	3.33	2.96
SF03	Femur	10.36	2.59	-0.37
SF04	Femur	34.04	4.44	2.96
SF05	Femur	20.72	2.59	0.74
SF06	Femur	14.80	3.70	0.37
SF07	Femur	12.21	2.96	-0.37
SF08	Femur	11.47	2.22	-0.04
SF09	Femur	20.72	4.44	4.44
SF10	Femur	9.62	2.96	0.11
SF11	Femur	27.38	5.55	3.33
SF12	Femur	148.74	18.87	16.28
SF13	Femur	12.21	2.96	4.07
SF14	Femur	17.02	4.07	-0.74

Sample #	Tissue	U-238 mBq/kg wet	U-238 error mBq/kg wet	U-235 mBq/kg wet
SF15	Femur	-2.22	1.85	-0.37
SF16	Femur	6.29	2.22	0.74
SK01	Knee	7.03	4.81	-1.85
SK02	Knee	10.36	4.07	2.22
SK03	Knee	15.17	5.18	-1.85
SK04	Knee	24.42	3.70	1.48
SK05	Knee	0.37	4.07	4.07
SK06	Knee			
SK07	Knee	223.85	20.72	34.78

Sample #	Tissue	U-235 error mBq/kg wet	U-234 mBq/kg wet	U-234 error mBq/kg wet
C09	Liver	0.74	34.78	2.96
C09	Lung	0.74	87.69	4.44
C09	Kidney	0.15	143.93	6.66
C09	Vertebrae	3.70	212.75	18.13
C09	Ribs	2.96	165.39	16.65
C09	Sternum	7.03	241.98	28.49
C10	Gonad	6.29	42.55	17.76
C10	Kidney	1.48	65.49	5.18
C10	L.N.	82.51	711.14	280.46
C10	Liver	0.19	6.29	1.11
C10	Ribs	3.70	59.94	13.69
C10	Spleen	0.74	8.51	1.85
C10	Thyroid	11.47	102.12	39.59
C10	Vertebrae	1.48	61.79	7.03
C11	Liver	0.37	7.40	1.11
C11	Lung	0.74	116.92	4.44
C11	Kidney	0.37	17.02	2.22
C11	Vertebrae	1.85	29.23	6.66
C11	Spleen	1.11	8.88	1.85
C11	Thyroid	12.21	40.33	24.05
C12	Liver	0.74	6.29	1.48
C12	Lung	0.74	71.41	4.07
C12	Kidney	1.11	26.64	3.33
C12	L.N.	21.46	112.85	38.11
C12	Vertebrae	3.70	23.31	11.84
C12	Ribs	1.11	19.24	4.07
C12	Sternum	1.48	4.44	3.33
C13	Vertebrae	4.07	66.23	14.06
C13	Ribs	1.11	34.41	5.92
C13	Sternum	1.85	46.62	6.66
C14	Liver	0.37	8.51	1.11
C14	Lung	0.74	38.48	2.59
C14	Kidney	0.74	29.60	3.33
C14	Spleen	0.37	3.70	0.74
C14	Vertebrae	1.11	23.31	4.81
C14	Gonad	3.70	9.62	8.51
C14	L.N.	33.30	285.64	92.50
C14	Thyroid	6.66	17.76	11.47
C15	Vertebrae	1.11	44.77	5.55
C15	Ribs	4.81	55.87	16.28
C15	Sternum	1.48	41.07	8.88
C15	L.N.	290.45	-157.62	494.69
C15	Thyroid	36.26	-2.22	35.15

Sample #	Tissue	U-235 error mBq/kg wet	U-234 mBq/kg wet	U-234 error mBq/kg wet
C15	Kidney	0.74	19.61	2.22
C15	Spleen	6.29	70.67	9.99
C15	Liver	0.74	16.28	1.85
C15	Lung	0.37	9.25	1.11
C16	Liver	0.37	3.33	1.11
C16	Lung	0.74	7.03	1.85
C16	Kidney	0.37	11.84	1.85
C16	L.N.	31.08	177.23	69.93
C16	Vertebrae	0.74	26.64	5.18
C17	Liver	0.15	8.14	0.74
C17	Lung	0.11	2.22	0.37
C17	Kidney	0.37	32.19	2.59
C17	Spleen	0.37	5.18	1.11
C17	L.N.	42.92	96.57	94.72
C17	Gonad	5.92	85.84	18.13
C17	Thyroid	8.14	44.40	14.80
C17	Vertebrae	0.74	16.65	2.22
C18	Liver	0.37	0.74	0.37
C18	Lung	0.74	8.88	1.48
C18	Kidney	1.11	6.66	1.48
C18	Spleen	0.74	2.22	0.74
C18	Thyroid	7.77	7.03	7.03
C19	Liver	0.11	-0.15	0.37
C19	Lung	0.37	6.29	1.11
C19	Kidney	1.11	-0.37	1.48
C19	Spleen	1.48	18.13	3.33
C19	Thyroid	8.51	14.43	17.02
C19	Gonad	2.96	2.22	5.55
C19	L.N.	28.49	225.33	68.08
C19	Vertebrae	1.11	9.25	2.59
C20	Liver	0.37	33.30	3.33
C20	Lung	1.11	138.75	5.92
C20	Kidney	0.37	21.46	3.33
C20	Spleen	1.11	12.58	2.96
C20	Thyroid	2.22	52.54	15.17
C20	Gonad			
C20	Ribs	2.22	69.93	11.47
C20	Vertebrae	1.48	52.54	5.55
C20	Sternum	1.11	22.20	4.07
C21	Liver	0.37	2.96	0.74
C21	Lung	0.37	1.85	0.74
C21	Kidney	1.48	14.80	4.07
C21	Spleen	0.74	5.55	1.85

Sample #	Tissue	U-235 error mBq/kg wet	U-234 mBq/kg wet	U-234 error mBq/kg wet
C21	Thyroid	26.64	96.57	60.31
C21	Vertebrae	7.03	67.34	15.91
C22	Liver	0.74	3.70	1.11
C22	Lung	0.37	19.61	1.48
C22	Kidney	1.11	16.28	3.70
C22	Spleen	0.74	4.44	1.85
C22	Thyroid	1.85	7.40	14.06
C22	Gonad	2.22	13.69	6.66
C22	Vertebrae	1.85	39.96	10.73
C22	L.N.	40.70	-44.40	81.40
C23	Liver	0.37	11.84	2.59
C23	Lung	0.37	1.48	1.11
C23	Kidney	1.11	21.09	3.70
C23	Spleen	0.74	0.37	2.22
C23	Thyroid	5.92	-6.29	8.88
C23	Gonad	7.77	1.85	26.64
C23	L.N.	21.09	24.05	59.20
C23	Vertebrae	1.11	6.29	1.85
82-N01	Liver	3.33	1.11	20.35
82-N01	Vertebrae	31.08	9.62	5.55
82-N02	Kidney	16.65	2.96	-0.37
82-N02	Liver	5.18	0.19	37.74
82-N02	Ribs	133.20	33.30	31.82
82-N02	Lung	8.14	0.74	1.48
82-N03	Kidney	7.40	2.96	
82-N03	Liver	2.22	0.74	5.18
82-N03	Vertebrae	8.88	4.81	7.77
82-N04	Kidney	25.53	4.07	3.70
82-N04	Liver	1.85	0.74	11.47
82-N04	Ribs	95.46	29.60	18.87
82-N04	Vertebrae	21.09	9.62	6.29
82-N05	Kidney	8.51	4.81	0.37
82-N05	Liver	2.96	0.74	2.59
82-N05	Vertebrae	31.45	7.03	19.24
82-N06	Kidney	7.77	2.22	0.37
82-N06	Liver	8.14	0.74	11.10
82-N06	Lung	21.09	1.85	4.07
82-N06	Vertebrae			9.25
82-N07	Kidney	15.91	2.59	-0.74
82-N07	Liver	9.99	1.48	29.97
82-N07	Lung	10.36	1.11	
82-N07	Ribs	46.62	14.06	30.34
82-N07	Vertebrae	15.17	7.77	12.58

Sample #	Tissue	U-235 error mBq/kg wet	U-234 mBq/kg wet	U-234 error mBq/kg wet
82-N08	Kidney	9.25	2.22	1.48
82-N08	Liver	7.77	1.11	37.37
82-N08	Lung	24.42	1.85	8.51
82-N08	Ribs	37.37	10.73	11.84
82-N08	Vertebrae	14.06	4.07	13.32
82-N09	Kidney	26.27	3.70	0.37
82-N09	Liver	3.33	0.74	15.91
82-N09	Lung	4.07	1.11	1.11
82-N09	Ribs	28.49	30.71	1.85
82-N09	Vertebrae	84.36	45.88	30.71
82-N10	Kidney	32.93	2.22	4.07
82-N10	Liver	4.44	0.74	30.34
82-N10	Lung	16.28	1.11	6.66
82-N11	Kidney	15.91	2.96	-1.11
82-N11	Liver	2.22	2.22	30.71
82-N11	Lung	25.90	1.85	15.17
82-N11	Ribs	58.09	12.21	7.77
82-N11	Vertebrae	18.50	6.29	29.97
82-N12	Kidney	9.25	1.11	0.74
82-N12	Liver	11.10	1.85	25.90
82-N12	Lung	8.51	0.74	
82-N12	Ribs	13.32	5.55	1.85
82-N12	Vertebrae	28.12	5.55	0.74
82-N13	Kidney	71.04	4.44	-0.15
82-N13	Liver	4.07	0.74	42.92
82-N13	Lung	15.91	1.11	
82-N13	Ribs	37.37	10.36	27.38
82-N13	Vertebrae	24.42	4.81	11.10
82-N14	Kidney	11.47	1.85	-0.04
82-N14	Liver	4.44	0.74	41.81
82-N14	Ribs	35.15	9.99	28.12
82-N14	Vertebrae	33.30	7.77	9.25
82-N15	Kidney	25.90	2.22	0.37
82-N15	Liver	14.80	1.48	41.81
82-N15	Lung	22.94	1.48	15.54
82-N15	Ribs	34.78	8.88	15.91
82-N15	Vertebrae	42.55	8.14	11.10
82-N16	Kidney	15.91	2.59	1.48
82-N16	Liver	4.07	0.74	41.81
82-N16	Lung	30.34	2.59	14.80
82-N16	Ribs	25.53	8.51	11.84
82-N16	Vertebrae	15.54	3.70	9.62
82-N17	Kidney	20.72	4.07	0.74

Sample #	Tissue	U-235 error mBq/kg wet	U-234 mBq/kg wet	U-234 error mBq/kg wet
82-N17	Liver	13.32	2.22	
82-N17	Lung	5.92	1.48	-1.48
82-N17	Ribs	33.67	8.14	-0.74
82-N17	Vertebrae	16.65	4.44	1.11
82-N18	Kidney	21.83	1.85	1.48
82-N18	Lung	33.67	2.96	5.18
82-N18	Ribs	26.64	13.69	5.92
82-N18	Vertebrae	26.27	8.88	4.07
83-N19	Kidney	52.17	5.18	1.11
83-N19	Liver	4.44	0.74	88.43
83-N19	Lung	22.94	1.48	12.21
83-N19	Ribs	19.61	8.88	5.92
83-N19	Vertebrae	15.91	4.81	11.84
83-N20	Kidney	23.68	2.96	1.48
83-N20	Liver	7.03	1.85	5.18
83-N20	Lung	9.99	1.85	
83-N20	Ribs	49.58	8.88	1.48
83-N20	Vertebrae	26.64	5.55	7.03
83-N21	Kidney	26.64	4.07	0.37
83-N21	Liver	3.70	0.74	33.30
83-N21	Lung	8.88	1.85	11.84
83-N21	Ribs	43.66	37.37	9.62
83-N22	Kidney	21.09	2.59	1.11
83-N22	Liver	8.14	0.74	9.25
83-N22	Lung	24.42	3.33	2.59
83-N22	Ribs	83.99	19.24	14.06
83-N22	Vertebrae	115.81	8.51	0.37
83-N23	Heart			
83-N23	Kidney	8.51	1.48	1.11
83-N23	Liver	9.25	2.59	35.52
83-N23	Lung	21.83	1.85	5.92
83-N23	Ribs	72.15	27.38	4.81
83-N23	Vertebrae	14.43	5.92	13.32
83-N24	Kidney	16.65	3.33	2.59
83-N24	Liver	9.99	3.70	72.15
83-N24	Lung	22.20	2.22	7.40
83-N24	Ribs	26.27	8.14	7.40
83-N24	Vertebrae	14.06	1.48	12.21
83-N25	Kidney	18.13	3.33	11.10
83-N25	Liver	8.88	1.85	31.45
83-N25	Lung	4.44	1.11	1.48
83-N25	Ribs	10.73	4.07	0.74
83-N25	Vertebrae	15.91	4.07	4.07

Sample #	Tissue	U-235 error mBq/kg wet	U-234 mBq/kg wet	U-234 error mBq/kg wet
83-N26	Kidney	7.03	2.22	-1.11
83-N26	Liver	4.07	1.11	9.62
83-N26	Lung	7.03	1.48	3.70
83-N26	Ribs	61.05	18.13	45.14
83-N26	Vertebrae	19.61	7.03	5.92
83-N27	Kidney	15.54	2.22	7.77
83-N27	Liver	9.25	1.85	21.83
83-N27	Lung	10.36	1.85	8.51
83-N27	Ribs	22.57	7.40	14.43
83-N27	Vertebrae	20.72	5.18	12.95
83-N28	Kidney	13.69	2.22	0.37
83-N28	Liver	6.29	1.85	21.83
83-N28	Lung	11.10	1.11	1.48
83-N28	Ribs	44.03	10.36	7.03
83-N29	Kidney	22.20	1.85	4.07
83-N29	Liver	15.17	1.11	168.35
83-N29	Lung	15.91	1.48	12.95
83-N29	Ribs	36.63	4.81	13.69
83-N29	Vertebrae	25.90	4.44	9.62
83-N30	Kidney	41.81	5.18	-1.11
83-N30	Liver	9.62	2.22	44.77
83-N30	Lung	11.84	1.85	2.96
83-N30	Ribs	28.12	8.51	-15.17
83-N30	Vertebrae	70.67	20.35	26.27
83-N31	Kidney	15.54	2.22	1.85
83-N31	Liver	8.88	1.11	48.47
83-N31	Ribs	45.51	11.84	15.54
83-N31	Vertebrae	13.69	3.70	7.40
83-N31	Lung	12.58	1.85	12.95
83-N32	Kidney	36.26	4.07	4.44
83-N32	Liver	16.28	2.59	11.47
83-N32	Ribs	28.49	6.66	12.21
83-N32	Lung	8.14	0.74	6.66
84-N33	Liver	10.73	1.48	2.96
84-N33	Lung	2.22	2.22	0.74
84-N33	Ribs	36.63	12.58	3.33
84-N33	Vertebrae	33.67	16.65	
84-N33	Kidney	6.66	6.66	7.77
84-N34	Kidney	71.04	5.18	-0.37
84-N34	Liver	108.41	6.29	1.48
84-N34	Lung	48.10	2.22	3.70
84-N34	Ribs	89.17	12.95	16.28
84-N34	Vertebrae	112.48	9.25	7.77

Sample #	Tissue	U-235 error mBq/kg wet	U-234 mBq/kg wet	U-234 error mBq/kg wet
84-N35	Kidney	18.13	2.96	2.22
84-N35	Liver	10.73	1.48	19.98
84-N35	Lung	26.64	1.85	13.32
84-N35	Ribs	58.09	12.95	17.39
84-N35	Vertebrae	59.94	13.32	17.39
84-N36	Kidney	25.90	3.33	1.11
84-N36	Liver	15.91	2.59	40.70
84-N36	Lung	27.75	2.96	11.10
84-N36	Ribs	842.12	36.63	14.80
84-N36	Vertebrae	32.19	7.77	11.47
84-N37	Kidney	14.80	2.59	0.04
84-N37	Liver	5.92	1.48	7.40
84-N37	Lung	10.36	1.48	2.59
84-N37	Ribs	28.12	17.76	1.11
84-N37	Vertebrae	95.46	30.34	24.42
84-N38	Kidney	8.14	2.59	-0.07
84-N38	Liver	7.03	1.48	20.72
84-N38	Lung	3.70	0.74	2.22
84-N38	Ribs	20.72	4.07	14.06
84-N38	Vertebrae	7.77	5.92	5.55
84-N39	Kidney	4.07	1.48	2.22
84-N39	Liver	-1.85	0.74	18.50
84-N39	Lung	5.55	1.48	0.74
84-N39	Ribs	10.36	6.66	5.18
84-N39	Vertebrae	10.73	4.07	8.88
84-N40	Kidney	5.55	1.48	0.74
84-N40	Liver	3.33	1.11	17.39
84-N40	Lung	6.66	1.48	5.55
84-N40	Ribs	8.88	6.29	52.54
84-N40	Vertebrae	9.99	4.44	5.18
84-N41	Kidney	17.02	2.96	0.37
84-N41	Liver	1.11	0.37	17.39
84-N41	Lung	11.47	1.11	3.33
84-N41	Ribs	-12.21	13.69	12.95
84-N42	Kidney	7.77	1.85	2.96
84-N42	Liver	1.11	1.11	14.06
84-N42	Lung	38.48	2.59	20.35
84-N42	Ribs	-0.11	7.40	21.09
84-N42	Vertebrae	-1.85		11.47
85-N43	Kidney	85.84	5.92	0.74
85-N43	Liver	-5.92	4.81	7.40
85-N43	Lung	0.74	1.11	1.48
85-N43	Ribs	60.68	8.51	15.54

Sample #	Tissue	U-235 error mBq/kg wet	U-234 mBq/kg wet	U-234 error mBq/kg wet
85-N43	Vertebrae	15.54	4.07	10.36
85-N44	Kidney	5.55	0.74	0.37
85-N44	Liver	7.40	1.11	34.78
85-N44	Lung	10.73	1.48	2.96
85-N44	Ribs	-1.11	0.74	-2.22
85-N44	Vertebrae	2.59	1.48	2.22
NF-27	Femur A			
NF-27	Femur B	57.35	10.73	14.43
NF-32	Femur A			3.33
NF-32	Femur B	86.95	13.69	
NF-37	Femur A	27.38	5.55	10.73
NF-37	Femur B	29.23	5.92	5.18
P04	Liver	0.37	2.96	1.11
P04	Vertebrae	0.74	12.58	2.59
P04	Ribs	1.48	9.62	3.70
P04	Gonad	4.07	12.21	8.88
P04	Lung	0.37	10.36	1.85
P04	Kidney	0.37	3.70	1.48
P04	Sternum	8.14	59.57	20.72
P04	L.N.	7.03	34.78	17.76
P04	Spleen	0.37	1.11	0.74
P04	Thyroid	15.17	29.97	38.11
P05	Liver	0.74	6.29	1.48
P05	Lung	1.11	60.68	4.07
P05	Kidney	0.74	23.31	3.70
P05	Vertebrae	0.37	6.29	1.48
P05	Ribs	1.48	11.47	4.07
P05	Sternum	2.59	9.99	11.47
P06	Liver	0.37	3.33	0.74
P06	Lung	0.74	37.37	2.59
P06	Kidney	0.74	4.07	2.22
P06	Vertebrae	0.74	14.06	2.22
P06	Ribs	0.74	19.61	4.44
P06	Sternum	4.07	54.02	16.28
P07	Liver	0.74	3.70	1.11
P07	Lung	0.37	11.47	1.85
P07	Kidney	0.74	12.21	2.22
P07	L.N.	94.72	361.49	160.21
P07	Vertebrae	1.11	7.77	2.59
P07	Ribs	2.59	17.02	6.29
P07	Sternum	3.33	67.34	15.54
P08	Liver	0.37	5.55	1.11
P08	Lung	0.37	10.73	1.11

Sample #	Tissue	U-235 error mBq/kg wet	U-234 mBq/kg wet	U-234 error mBq/kg wet
P08	Kidney	0.74	11.47	2.59
P08	Spleen	0.37	11.84	1.85
P08	Thyroid	11.84	124.32	33.67
P08	L.N.	5.55	50.32	12.95
P08	Ribs	1.11	9.25	3.33
P08	Sternum	5.92	64.01	19.61
P08	Vertebrae	0.74	9.25	2.22
P09	Lung	0.37	14.43	1.48
P09	Kidney	2.22	26.27	4.81
P09	Spleen	0.37	9.99	1.85
P09	Gonad	1.85	45.14	12.95
P09	Ribs	0.74	12.58	2.22
P09	Sternum	6.29	41.44	17.76
P09	Vertebrae	0.37	25.16	2.22
P10	Liver	0.37	2.22	0.37
P10	Lung	0.37	18.13	1.85
P10	Kidney	0.74	6.66	2.59
P10	Spleen	0.11	2.59	1.11
P10	Vertebrae	1.11	39.96	4.44
P10	Ribs	1.85	18.50	4.44
P10	Sternum	25.90	359.64	80.66
P11	Liver	0.37	7.03	1.48
P11	Lung	0.37	0.74	0.37
P11	Kidney	0.74	-0.11	0.74
P11	Spleen	0.37	-2.22	1.11
P11	Thyroid	5.18	-22.20	9.99
P11	L.N.	39.22	-153.18	44.03
P11	Gonad	2.59	-4.81	5.55
P11	Ribs	1.11	23.68	2.59
P11	Sternum	4.81	39.22	10.73
P11	Vertebrae	0.37	29.97	3.33
P12	Thyroid	4.44	-40.70	
P12	Liver	0.37	-0.37	0.37
P12	Lung	0.37	23.68	1.85
P12	Kidney	1.11	14.06	2.59
P12	Gonad	3.33	-24.05	5.18
P12	Spleen	0.37	-0.74	1.11
P12	Sternum	6.29	-4.07	5.18
P12	L.N.	21.83	339.29	59.20
P12	Ribs	1.11	2.22	1.85
P12	Vertebrae	0.74	9.25	1.48
P13	Liver	0.15	4.44	0.74
P13	Lung	0.37	8.14	1.11

Sample #	Tissue	U-235 error mBq/kg wet	U-234 mBq/kg wet	U-234 error mBq/kg wet
P13	Kidney	1.11	14.80	2.96
P13	Spleen	1.48	4.07	3.33
P13	Thyroid	4.44	-9.62	13.32
P13	Gonad	4.07	9.99	9.40
P13	L.N.	17.02	193.88	46.99
P13	Ribs	0.74	5.92	2.22
P13	Sternum	11.47	59.57	28.49
P13	Vertebrae	0.74	18.87	2.59
P14	Lung	0.37	4.81	1.11
P14	Kidney			
P14	Liver	0.37	2.59	0.74
P14	Spleen	0.74	0.37	1.48
P14	Thyroid	3.70	97.68	24.79
P14	Gonad		15.91	9.99
P14	L.N.	10.36	17.39	22.57
P14	Ribs	1.11	11.47	2.96
P14	Sternum	4.44	28.86	10.73
P15	Spleen	1.48	4.81	2.22
P15	L.N.	16.65	-76.96	36.26
P15	Liver	0.37	0.74	0.74
P15	Lung	0.37	12.58	1.85
P15	Kidney	1.48	-1.85	4.07
P15	Thyroid	5.55	6.66	9.99
P15	Gonad	5.92	-1.85	11.84
P16	Liver	0.37	6.66	1.48
P16	Lung	0.74	22.20	3.33
P16	Kidney	0.37	5.55	2.22
P16	Spleen	0.74	7.03	2.22
P16	Thyroid	6.66	-11.84	18.50
P16	L.N.	7.40	31.08	19.61
P17	Kidney	0.74	5.55	1.85
P17	Thyroid	27.75	35.52	42.18
P17	L.N.	3.70	69.93	10.36
P17	Gonad	3.33	-19.24	7.77
S01	Kidney	0.74	41.07	3.33
S01	Liver	0.19	14.06	1.48
S01	Lung	1.48	54.02	5.92
S01	Ribs	2.59	31.82	8.14
S01	Vertebrae			
S02	Kidney	1.11	21.83	4.07
S02	Liver	0.11	5.18	0.74
S02	Lung	0.15	19.61	1.11
S02	Ribs	7.03	90.28	21.46

Sample #	Tissue	U-235 error mBq/kg wet	U-234 mBq/kg wet	U-234 error mBq/kg wet
S02	Vertebrae	0.37	17.39	2.59
S03	Kidney	1.11	85.47	6.66
S03	Kidney	0.74	60.68	3.70
S03	Liver	0.74	47.36	3.33
S04	Kidney	0.74	60.31	4.44
S04	Liver	0.15	30.71	1.11
S04	Lung	0.37	35.15	2.22
S04	Vertebrae	0.74	15.91	2.96
S05	Kidney	0.74	8.51	2.59
S05	Liver	0.74	7.03	1.85
S05	Lung	0.37	22.20	2.22
S05	Ribs	1.11	21.46	5.55
S05	Vertebrae	1.48	26.27	4.07
S06	Kidney	0.37	18.87	2.22
S06	Liver	0.37	28.12	1.85
S06	Lung	0.74	34.04	2.59
S06	Vertebrae	0.74	15.91	3.70
S07	Kidney	3.33	58.09	11.10
S07	Liver	0.37	13.32	1.48
S07	Vertebrae	1.85	132.46	8.88
S08	Kidney	0.37	15.91	2.22
S08	Liver	0.37	4.81	0.74
S08	Lung	0.37	29.23	2.59
S08	Ribs	5.18	44.77	11.10
S09	Kidney	4.81	152.81	22.57
S09	Liver	0.15	4.81	0.74
S09	Lung	0.37	62.53	2.59
S09	Ribs	13.32	101.01	24.79
S09	Vertebrae	0.37	22.20	2.96
SF01	Femur	5.55	54.39	11.10
SF02	Femur	1.48	11.84	2.96
SF03	Femur	1.11	8.88	2.22
SF04	Femur	1.48	35.15	4.81
SF05	Femur	0.74	12.58	2.22
SF06	Femur	1.85	30.34	5.18
SF07	Femur	0.74	9.25	2.96
SF08	Femur	1.11	24.79	2.96
SF09	Femur	2.59	17.39	4.07
SF10	Femur	1.11	30.34	5.18
SF11	Femur	2.22	27.01	5.55
SF12	Femur	6.29	241.98	24.05
SF13	Femur	1.85	28.86	4.44
SF14	Femur	1.11	21.46	4.81

Sample #	Tissue	U-235 error mBq/kg wet	U-234 mBq/kg wet	U-234 error mBq/kg wet
SF15	Femur	1.11	-1.11	1.11
SF16	Femur	1.48	9.62	2.59
SK01	Knee	1.85	22.57	6.66
SK02	Knee	1.48	23.68	5.18
SK03	Knee	1.85	28.12	6.66
SK04	Knee	1.11	32.93	4.07
SK05	Knee	2.22	8.88	5.55
SK06	Knee			
SK07	Knee	8.51	381.84	27.01

APPENDIX B

129/127 I Ratios-Human Thyroid

Sample #	Date of Death	Ratio x 10^(-9)	Error x 10^(-9)	Residence
AV-12	30-Jul-46	0.18	0.17	S.L.C., UT
AV-59	24-Mar-47	0.07	0.10	Unknown
AV-63	19-Apr-47	0.30	0.08	Unknown
AV-65	22-Apr-47	0.15	0.07	Unknown
AV-72	21-Jun-47	1.51	0.14	Unknown
AV-73B	23-Jun-47	1.07	0.36	Unknown
AV-90	18-Sep-47	1.32	*.**	S.L.C., UT
AV-92	20-Sep-47	0.03	0.04	Unknown
AV-93	21-Sep-47	1.45	0.12	Unknown
AV-94B	25-Sep-47	0.24	0.10	Unknown
AV-96	04-Oct-47	0.99	0.36	Unknown
AV-98	17-Oct-47	2.36	*.**	Unknown
AV-107B	18-Oct-47	2.09	0.32	Unknown
AV-109	25-Oct-47	0.74	0.19	S.L.C., UT
AV-101	30-Oct-47	1.49	0.12	Unknown
AV-110	29-Nov-47	4.14	*.**	Monroe, UT
AV-124A	01-Jan-48	3.16	0.39	Unknown
AV-128	26-Jan-48	4.52	0.99	Unknown
AV-126	04-Feb-48	1.47	0.27	Unknown
AV-129	27-Feb-48	1.65	0.12	Granger, UT
AV-146	02-Apr-48	1.39	0.13	Unknown
AV-145	24-Apr-48	0.37	0.33	Lewiston, UT
AV-170	07-Aug-48	1.81	0.42	Unknown
AV-189	02-Nov-48	0.11	0.15	Unknown
AV-190	08-Nov-48	2.17	0.30	Unknown
AV-194	19-Nov-48	2.51	0.44	S.L.C., UT
AV-196	20-Nov-48	1.19	0.15	Unknown
AV-271	23-Sep-49	0.52	*.**	Draper, UT
AV-306	19-Feb-50	11.27	*.**	Beverly Hills, CA
AV-334	23-Jun-50	1.30	1.69	Ogden, UT
AV-330	24-Jun-50	1.06	0.60	S.L.C., UT
AV-335	24-Jun-50	0.97	0.97	Unknown
AV-336	24-Jun-50	0.37	0.17	Ogden, UT
AV-347	09-Aug-50	2.11	1.85	Unknown
AV-353	16-Sep-50	0.41	0.12	Magna, UT
AV-399	11-Mar-51	1.68	0.19	S.L.C., UT
AV-400	12-Mar-51	1.39	0.87	Pocatello, ID
AV-408	05-Apr-51	0.64	0.66	Pocatello, ID
AV-412	16-Apr-51	2.10	0.40	S.L.C., UT
AV-418	27-May-51	1.79	0.13	S.L.C., UT
AV-428	05-Jul-51	1.49	0.22	Ogden, UT
AV-430	15-Jul-51	2.20	0.25	Richfield, UT
AV-439	23-Jul-51	0.23	0.41	S.L.C., UT
AV-455A	11-Sep-51	2.17	0.22	S.L.C., UT
AV-459A	25-Sep-51	2.00	0.22	Kaysville, UT

AV-488	05-May-52	1.12	1.29	S.L.C., UT
AV-520	01-Jun-52	0.32	0.11	S.L.C., UT
AV-533B	08-Jun-52	1.96	0.39	S.L.C., UT
AV-545A	07-Jul-52	2.66	0.27	S.L.C., UT
AV-547	11-Jul-52	2.92	0.46	S.L.C., UT
AV-554	15-Aug-52	1.38	0.16	St. George, UT
AV-565	23-Sep-52	1.42	0.42	S.L.C., UT
AV-570	16-Oct-52	1.38	0.18	Murray, UT
AV-576	05-Nov-52	2.55	0.21	Rigby, ID
AV-580	10-Nov-52	0.00	0.00	S.L.C., UT
AV-587	17-Dec-52	1.90	0.41	Murray, UT
AV-597	09-Jan-53	2.91	0.36	Unknown
AV-600	13-Jan-53	0.92	0.29	Monroe, UT
AV-602	21-Jan-53	1.69	0.14	S.L.C., UT
AV-611	13-Feb-53	2.16	0.51	S.L.C., UT
AV-612	14-Feb-53	1.38	0.16	S.L.C., UT
AV-614	15-Feb-53	0.49	0.67	Yakima, WA
AV-619	25-Feb-53	3.07	0.36	S.L.C., UT
AV-621	27-Feb-53	3.47	0.59	S.L.C., UT
AV-622	28-Feb-53	0.69	0.22	Salina, UT
AV-623	02-Mar-53	1.56	0.86	S.L.C., UT
AV-635	06-Apr-53	1.38	0.52	S.L.C., UT
AV-636	10-Apr-53	1.71	0.28	S.L.C., UT
AV-640B	30-Apr-53	1.97	3.11	S.L.C., UT
AV-641	13-May-53	1.45	0.16	Pioche, NV
AV-644	24-May-53	0.39	0.16	Shelley, ID
AV-647	03-Jun-53	0.21	0.10	Grace, ID
AV-672	29-Sep-53	0.24	0.77	Ogden, UT
AV-673	04-Oct-53	4.24	1.61	Pocatello, ID
AV-677	31-Oct-53	3.53	0.72	Mt. Pleasant, UT
AV-683	04-Dec-53	2.54	0.20	Ogden, UT
AV-685	16-Dec-53	0.59	0.56	S.L.C., UT
AV-691	08-Jan-54	0.13	0.52	S.L.C., UT
AV-694	14-Jan-54	3.98	0.37	Draper, UT
AV-695	15-Jan-54	0.97	0.56	S.L.C., UT
AV-697B	30-Jan-54	1.97	0.20	Lark, UT
AV-701	16-Feb-54	0.72	0.06	S.L.C., UT
AV-706	12-Mar-54	1.56	0.29	Unknown
AV-707	27-Mar-54	1.41	0.28	S.L.C., UT
AV-710	09-Apr-54	2.17	0.24	S.L.C., UT
AV-715A	07-May-54	2.16	0.14	Nampa, ID
AV-716	04-Jun-54	1.82	0.12	S.L.C., UT
AV-724	07-Jul-54	0.61	0.78	Tooele, UT
AV-731	24-Jul-54	2.56	0.29	S.L.C., UT
AV-749	21-Sep-54	2.94	0.22	Parowan, UT
AV-754	14-Oct-54	1.50	0.30	St. Anthony, ID

AV-756	18-Oct-54	2.36	0.21	S.L.C., UT
AV-757	20-Oct-54	0.07	0.45	S.L.C., UT
AV-774A	28-Dec-54	0.78	0.47	Roosevelt, UT
AV-783	27-Feb-55	0.25	0.57	S.L.C., UT
AV-790	04-Mar-55	1.30	0.43	Logan, UT
AV-788	19-Mar-55	0.11	0.47	St. George, UT
AV-794	09-May-55	0.33	0.12	Helper, UT
AV-796	14-May-55	3.00	0.48	S.L.C., UT
AV-803	14-May-55	0.16	0.71	Dutluth, MN
AV-800	20-May-55	0.95	0.77	S.L.C., UT
AV-804	20-Jun-55	1.04	0.12	S.L.C., UT
AV-807	01-Jul-55	1.19	1.19	Willard, UT
AV-809	05-Jul-55	1.64	0.55	Idaho Falls, ID
AV-810	06-Jul-55	0.92	0.32	Unknown
AV-812	15-Jul-55	9.92	10.62	Green River, WY
AV-819	13-Aug-55	0.25	0.21	Preston, ID
AV-821	25-Aug-55	0.28	0.56	S.L.C., UT
AV-832	07-Oct-55	0.31	0.31	Ogden, UT
AV-847	21-Dec-55	0.66	0.24	Rigby, ID

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